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REMOTE STORAGE

ALTGELD HALL STACKS

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MINUTES OF PROCEEDINGS

OF

The Engineering Association

OF

NEW SOUTH WALES.

ALSO,

ACT OF INCORPORATION, RULES AND BY-LAWS,

AND

LIST OF MEMBERS.

VOL. II.

Edited by GUSTAVE FISCHER,

HON. SECRETARY ENG. ASSOC. OF N.S.W.

SYDNEY:

Published by the Association,

5 O'CONNELL STREET,

1887.

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ADVERTISEMENT.

THE Association, as a body, is not responsible for the facts and opinions advanced in the following pages.

Sydney: Printed by TURNER & HENDERSON, Hunter-street.

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REMOTE STORAGE

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ERRATA.

Page 60, line 1 from bottom, for "points A B" read "points B and A."

Page 61, line 3 from top, for "A" read "B."

Page 61, line 6 from top, for "B" read "A."

Page 61, lines 11 and 12 from top, for $\frac{\text{"2 n"}}{t}$ read $\frac{\text{"2 N."}}{t}$

Page 61, line 15 from top, for "7182·5" read "7812·5."

Page 64, line 7 from top, for "diameter" read "radius."

Page 67, column 7, for "Stock 23·125" read "23·625."

Page 67, column 6, for "Red 36·01" read "36·09."

Pages 68, 69, and 73, Tables II. and IV., erase remarks in last column for Nos. 10 to 36, 100 to 104, and 106 to 117 inclusive, and substitute the following "Note :—(Tables II. and IV.) In every case where only one stress is given the joints yielded either both together or one immediately after the other, and where two stresses are given the figures opposite (1) denote the stress at which first joint yielded, and the figures opposite (2) the stress at which second joint yielded."

Page 70, column 7, for "19·27" read "18·94," and column 8, for "1·100" read "1·000," and for "0·1126" read "0·1107."

Page 74, column 5, No. 131, insert "failed."

Page 90, lines 6 and 12 from bottom, for "Labini" read "Sabini."

Page 96, line 6 from top, insert "deposit" after shelving, and erase "deposits" in line below.

Page 96, paragraph 3, "The Botany sands, &c.," should be at top of page.

Page 100, line 12 from bottom, for "flow" read "floor."

Page 103, line 14 from bottom, for "drainage" read "damage."

ACT OF INCORPORATION.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES INCORPORATION.

An Act to Incorporate a Society called the "Engineering Association of New South Wales." [19th August, 1884.]

Preamble.

WHEREAS a Society called the "ENGINEERING ASSOCIATION OF NEW SOUTH WALES" has under certain rules and by-laws been formed at Sydney in the Colony of New South Wales for the general advancement of Engineering and Mechanical Science And whereas the Council of the said Society is at the present time composed of the following office-bearers and members Owen Blacket Consulting Engineer President Henry Selfe Government Engineer Surveyor Vice-President John Sands Mechanical Engineer Honorary Treasurer John Parry Honorary Librarian William Eugene Hort Nicolle Secretary and John Trevor Jones City Engineer Adrien Charles Mountain City Surveyor Walter Shellshear Assoc. M. Inst. C.E. Henry Davies Civil Engineer Max Thomson Civil Engineer and Robert Pollock Mechanical Engineer Members of the Council And whereas it is expedient that the said Society should be incorporated and should be invested with the powers and authorities hereinafter contained Be it therefore enacted by the Queen's Most Excellent Majesty by and with the advice and consent of the Legislative Council and Legislative Assembly of New South Wales in Parliament assembled and by the authority of the same as follows:—

Interpretation Clause.

1. For the purposes of this Act the following words in inverted commas shall unless the context otherwise indicate bear the meaning set against them respectively—

"Corporation"—The Society hereby incorporated.

"Council"—The members of the Council at any duly convened meeting thereof at which a quorum according to the by-laws at the time being shall be present.

"Secretary"—Such person or either one of such persons who shall for the time being be the Secretary or Secretaries honorary or otherwise of the said Society (saving and excepting any Assistant Secretary of the said Society).

Incorporation Clause.

2. The President Vice-President Officers and Members of the said Society for the time being and all persons who shall in manner provided by the rules and by-laws for the time being of the said Society become members thereof shall be for the purposes hereinafter mentioned a body corporate by the name or style of the "Engineering Association of New South Wales" and by that name shall and may have perpetual succession and a common seal and shall and may enter into contracts sue and be sued plead and be impleaded answer and be answered to defend and be defended in all Courts and places whatsoever and may prefer lay and prosecute any indictment information and prosecution against any person whomsoever and any summons or other writ and any notice or other proceeding which it may be requisite to serve upon the Corporation may be served upon the Secretary or one of the Secretaries as the case may be or if there be no Secretary or if the Secretaries or Secretary be absent from the Colony then upon the President or Vice-President.

Rules and By-laws.

3. The present rules and by-laws of the said Society shall be deemed and considered to be and shall be the rules and by-laws of the said Corporation save and except in so far as any of them are or shall or may be altered varied or repealed under the powers for that purpose therein contained or are or may be inconsistent or incompatible with or repugnant to any of the provisions of this Act or any of the laws now or hereafter to be in force in the said Colony.

Power to hold and deal with lands.

4. The Corporation shall have power to purchase acquire and hold lands and any interest therein and also to sell and dispose of the said lands or any interest therein and all lands tenements hereditaments and other property of whatever nature now belonging to the said Society under the said rules and by-laws or vested in Trustees for them shall on the passing of this Act be vested in and become the property of the said Corporation subject to all charges and claims and demands in anywise affecting the same.

Property vested in Corporation.

Ordinary business to be managed by the Council.

5. The ordinary business of the Corporation in reference to its property shall be managed by the Council and it shall not be lawful for individual members to interfere in any way in the management of the affairs of the Corporation except as by the rules and by-laws for the time being shall be specially provided.

Powers of Council.

6. The Council shall have the general management and superintendence of the affairs of the Corporation and excepting the appointment of Presidents and Vice-Presidents and other honorary officers who shall be appointed as the by-laws of the Society shall from time to time provide the Council shall have the appointment of all officers and servants required for carrying out the purposes of the Society and of preserving its property and it may also define the duties and fix the salaries of all officers Provided that if a vacancy should occur in the Council during any current year of the Society's proceedings it shall be lawful for the Council to elect a member of the Society to fill such vacancy for the unexpired portion of the then current year The Council may also purchase or rent land houses or offices and erect buildings or other structures for any of the purposes for which the Society is hereby incorporated and may borrow money for the purposes of the Corporation on mortgages of the real and chattel property of the Corporation or any part thereof or may borrow money without security provided that the amount so borrowed without security shall never exceed in the aggregate the amount of the income of the Corporation for the last preceding year and the Council may also settle and agree to the covenants powers and authorities to be contained in the securities aforesaid.

Liability of Members.

7. In the event of the funds and property of the Corporation being insufficient to meet its engagements each member thereof shall in addition to his subscription for the then current year be liable to contribute a sum equal thereto towards the payment of such engagements but shall not be otherwise individually liable for the same and no member who shall have commuted his annual subscription shall be so liable for any amount beyond that of one year's subscription.

Custody and use of Common Seal.

8. The Council shall have the custody of the common seal of the Corporation and have power to use the same in the affairs and business of the Corporation and for the execution of any of the securities aforesaid and may under such seal authorise any person without such seal to execute any deed or deeds and do such other matter as may be required to be done on behalf of the Corporation but it shall not be necessary to use the said seal in respect to the ordinary business of the Corporation nor for the appointment of their Secretaries Solicitor or other officers.

Copy of By-laws to be evidence.

9. The production of a printed or written copy of the rules and by-laws of the Corporation certified in writing by the Secretary or one of the Secretaries as the case may be to be a true copy and having the common seal of the Corporation affixed thereto shall be

conclusive evidence in all Courts of such rules and by-laws and of the same having been made under the authority of this Act.

Elections not made in due time may be made subsequently.

10. In case any of the elections directed by the rules and by-laws for the time being of the Corporation to be made shall not be made at the times required it shall nevertheless be competent to the Council or to the members as the case may be to make such elections respectively at any ordinary meeting of the Council or at any annual or special general meeting held subsequently.

President, Vice-President or Secretary may represent Corporation for certain purposes.

11. The President or Vice-President or the Secretary or either one of the Secretaries may represent the Corporation in all legal and equitable proceedings and may for and on behalf of the Corporation make such affidavits and do such acts and sign such documents as are or may be required to be done by the plaintiff or complainant or defendant respectively in any proceeding to which the Corporation may be parties.

12. This Act may be cited as the "Engineering Association Incorporation Act of 1884."

RULES AND BY-LAWS.

RULES AND BY-LAWS.

Section I.

OBJECTS.

The Engineering Association of New South Wales was first established, and has since been incorporated by Act of Parliament, for the general advancement of Engineering and Mechanical Science, and more particularly those branches of Civil and Mechanical Engineering which tend to develope the resources of Australia, and to receive and discuss at its stated meetings original papers on Civil and Mechanical Engineering.

Section II.

CONSTITUTION.

1. The Engineering Association of New South Wales shall consist of Members who are entitled to the privileges of Corporate Membership, also Honorary Members, Associates and Students, who are not entitled to the privileges of Corporate Membership.

2. Every Candidate for election into the class of Member shall be more than twenty-one years of age, and must be actually engaged in some branch of Engineering, and must be considered by the Council to be qualified for election.

3. Associates to be gentlemen not under twenty-four years of age, who from their scientific attainments or position in society, may be considered eligible for election by the Council.

4. HONORARY MEMBERS shall be persons who have been eminent benefactors to this or some other of the Australian Colonies, and distinguished patrons and promoters of Engineering and Manufacturing industries. Honorary members shall be exempted from payment of fees and contributions; they may attend the meetings of the Association, and they shall be furnished with copies of the publications of the Association, but they shall have no right to hold office, to vote, or otherwise interfere in the business of the Association. The number of Honorary Members shall not at any one time exceed twenty, and not more than two Honorary Members shall be elected in any one year.

5. STUDENTS shall be persons not under sixteen years of age who are students in engineering at a University, or who are apprenticed or articled to any branch of Engineering, and may afterwards be admitted as Members at the discretion of the Council. Such persons may continue Students until they attain the age of twenty-two years, but not longer.

6. The Officers of the Association shall be a President, Vice-President, Secretary, Honorary Secretary, Honorary Treasurer, and six other Members of Council, being eleven persons, who shall constitute the Council to direct and manage the concerns of the Association; also two Auditors of Accounts, and a Librarian. Such officers shall be elected or appointed annually in manner hereinafter directed.

SECTION III.

ELECTION AND EXPULSION OF MEMBERS, ASSOCIATES, HONORARY MEMBERS, AND STUDENTS.

1. Any person desirous of being elected a Member, Associate, or Student, must be proposed and recommended

according to Form No. 1. All recommendations for admission to be signed by not less than five members if the application be for admission as a Member or Associate, and by three members if it be for a Student.

2. The proposal so made being delivered to the Secretary, shall be submitted to the Council, who, on approving the qualifications of the candidate, shall present the application for ballot.

3. The elections to take place by ballot. All recommendations for admission to go to the ballot unless unanimously rejected by the Council. The approved ballot list to be signed by the President, and copies forwarded to the members. Elections to take place at the ordinary General Meetings.

4. The proportion of votes for deciding the election of any candidate shall be at least four-fifths of the number voting, twenty members at least to record their votes.

5. Any person duly elected a Member, Associate, or Student, shall be informed thereof without delay, by a letter, according to Form No. 2, enclosing a promise (Form No. 3) to abide by the Act of Incorporation, Rules and By-laws of the Association, which promise the person elected must sign and return to the Secretary, and he must pay the admission fee and subscription for the current half-year within two months after the date of his election, which otherwise shall become void, but the Council may, in particular cases, extend the time.

6. Every person proposed as an Honorary Member must be recommended by the Council and elected by ballot.

7 A majority of members present at any Ordinary Meeting shall have the power to expel an obnoxious member from the Association, provided that a resolution to

that effect has been moved and seconded at the previous Ordinary Meeting, and that due notice of the same has been sent in writing to the member in question within a week after the meeting at which such resolution has been brought forward. The vote to be taken by ballot.

Section IV.

ELECTION OF COUNCIL AND OFFICERS.

1. The President, Vice-President, Honorary Treasurer, Honorary Secretary, and the six other Members of Council, shall be elected annually by ballot, at the Annual General Meeting to be called in October.

2. The Secretary and Librarian shall be appointed annually by the Council at their first Meeting after Annual General Meeting.

3. Any vacancies occurring in the Council during the year may be filled up by the Council.

4. It shall be the duty of the Council each year to prepare a list containing the names of Members whom they recommend for election, to the respective offices of President, Vice-President, Honorary Treasurer, and Honorary Secretary, together with the names of six other Members whom they recommend for election as ordinary Members of Council. The names thus recommended shall be proposed at one meeting of the Council, and agreed to at a subsequent meeting. Such list shall be suspended in the Association's Room, and a copy shall be sent to each ordinary Member not less than seven days before the day appointed for the Annual General Meeting.

5. Each Member present at the Annual General Meeting shall have the power to alter the list of names recommended by the Council, by adding to it the names of any eligible Members not already included in it and remov-

ing from it an equivalent number of names, and he shall use this list, with or without such alterations, as a balloting list at the election of Officers and Council.

6. No ballot for the election of Members of Council or of Officers shall be valid unless twenty members at least shall record their votes.

7. Two Auditors shall be appointed at the Ordinary General Meeting in August or September, who shall audit the accounts and lay them before the Annual General Meeting in October.

Section V.

CONTRIBUTIONS TO THE FUNDS.

1. Each Member shall pay two guineas, and each Associate two guineas, and each Student one half-guinea per annum.

2. Every new Member or Associate shall pay an admission fee of two guineas, and every Student shall pay an admission fee of one guinea.

3. All Subscriptions to be payable half-yearly in advance, in the months of April and October.

4. Any Member or Associate whose Subscription is not in arrears, may pay the amount of ten annual payments at any time as a life composition for the ordinary annual payments.

5. Members or Associates whose Subscriptions are twelve months in arrears, will not be entitled to any of the privileges of the Association. The name of any Member or Associate who shall be two years in arrears with his Subscriptions shall be erased from the list of Members and Associates; but such Member may be re-admitted on giving a satisfactory explanation to the Council, and on payment of arrears.

6. Every individual elected a Member, Associate or Student, shall be liable for the payment of his Annual Subscriptions, until he has signified to the Secretary, in writing, his desire to resign, having previously paid all arrears, or until he has forfeited his right to remain in, or to be attached to the Association.

Section VI.

THE PRESIDENT.

1. The President shall take the chair at all Meetings of the Association, the Council, and the Committees, at which he is present, and shall regulate and keep order in the proceedings.

2. In the absence of the President, it shall be the duty of the Vice-President to take the chair.

3. In the absence of both the President and Vice-President, the meeting may elect any Member of Council, or in case of their absence, any Member present to take the chair at the meeting.

Section VII.

THE COUNCIL.

1. The Council to be elected according to the provisions of Section IV. shall consist of the President, Vice-President, Honorary Treasurer, Secretary, Honorary Secretary, and six other Members of Council.

2. The direction and management of the concerns of the Association are vested in the Council, under the control of the Act of Incorporation, Rules and By-Laws.

3. The Council shall meet as often as the business of the Association may require; and at every meeting three shall constitute a quorum. The Council may appoint Committees, for special purposes, to report to the Council.

4. The Council shall draw up a yearly Report on the state of the Association, which shall be read at the Annual General Meeting.

5. The funds of the Association shall be lodged at a bank approved of by the Association. Claims against the Association, when approved by the Council, shall be paid by the Treasurer. All payments to be made by cheques, signed by the Treasurer, and countersigned by the Secretary.

Section VIII.

THE SECRETARIES.

It shall be the duty of the Secretaries, under the direction of the Council, to conduct the correspondence of the Association; to attend all meetings of the Association, and of the Council, and of Committees; to take minutes of the proceedings of such Meetings, and all communications that may be ordered to be read; to superintend the publication of such papers as the Council may direct; to have charge of the Library; to direct the collection of the Subscriptions, and the preparation of the account of the expenditure of the funds, and to present all accounts to the Council for inspection and approval.

Section IX.

MEETINGS.

1. The Ordinary General Meetings of the Association shall be held on the second Thursday of each month, subject to alteration by the Council with due notice.

2. At the Ordinary General Meetings the business shall be transacted in the following order, unless the Chairman specially decide otherwise:—

(1) The Minutes of the preceding meeting to be read, and after having been confirmed, to be signed by the Chairman.

(2) Business arising out of the Minutes to be entered on.

(3) Communications from the Council to be brought forward.

(4) Ballot for the election of new Members.

(5) New Members to enrol their names and be introduced.

(6) Donations to be laid on the table and acknowledged.

(7) Papers to be read and discussed.

3. Every Member shall have the privilege of introducing one stranger, to be present at the ordinary Meetings of the Association, on writing his name in a book provided for that purpose.

4. The Annual General Meeting of the Association shall be held on the second Thursday in October, at eight o'clock in the evening, to receive and deliberate upon the Report of Council with the Annual Statement of the Accounts, and to elect the Council and Officers for the ensuing year.

5. The Council may, at any time, call a Special General Meeting of Corporate Members for a specific purpose relative to the direction and management of the concerns of the Association; and the Council are at all times bound to do so on a requisition in writing of twelve Corporate Members, specifying the nature of the business to be transacted.

6. A notice shall be sent to the Corporate Members at least seven days before the time appointed by the Council for such Special General Meeting, and the notice shall specify the nature of the business to be transacted, and no other than that business shall be transacted at that meeting, and twenty shall constitute a quorum.

Section X.

ENACTMENT OF RULES AND BY-LAWS.

No new Rule, or By-Law, or alteration or repeal of existing Rules or By-Laws, shall be made, unless carried at two successive General Meetings, at each of which twenty members, at least, must be present.

Section XI.

PAPERS AND ORIGINAL COMMUNICATIONS.

1. All Papers and Original Communications must be forwarded to the Secretary, who will lay them before Council; and if approved, notice will be given, and the papers read and discussed.

2. Any subject connected with engineering may be brought forward for discussion before the Association, provided the Member bringing the matter forward has first asked for and obtained the sanction of the Council.

Section XII.

THE PROPERTY OF THE ASSOCIATION.

1. The property and effects of the Association, of what kind soever, are vested in the Corporate Members for the time being for the use of the body politic and corporate solely in furtherance of the public and scientific objects contemplated in the Act of Incorporation.

2. Every Paper, Map, Plan, Drawing, or Model, presented to the Association shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper.

3. The Library shall be open for consultation and for the issue and return of books, subject to such regulations as the Council may deem necessary.

APPENDIX TO THE BY-LAWS.

Form No. 1.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Nomination Paper.

Name in full

Designation or Occupation

Business Address

being of the required age, and desirous of admission into the Engineering Association of New South Wales, we, the undersigned, from our personal knowledge propose and recommend him as a proper person to become a thereof. (Member, Associate, or Student to be inserted by proposer.)

Witness our hands this day of 18

PROPOSED BY

SECONDED BY

} Five Members' Signatures are required for Member or Associate, and Three for a Student.

Signature of Candidate.

Form No. 2.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

(*Established* 1870. *Incorporated* 1884.)

Sir, Sydney, 18

I have the honor to inform you that you have this day been elected a of the Engineering Association of New South Wales, and I beg to forward to you a copy of the Act of Incorporation, Rules and By-Laws of the Association.

According to the Rules of the Association you are required as to pay being your admission fee and subscription for the current half-year, and to return the accompanying obligation with your signature within two months of the date of your election, otherwise your election will be void. These conditions being complied with, you will be considered as admitted into the Association, when any publications or notices to which you are entitled will be forwarded according to your directions.

I beg to direct your attention to section V. of the By-Laws, and to point out that all half-yearly subscriptions become due in the months of April and October in each half-year for the half-year then commencing.

I have, &c.,

Secretary.

Form No. 3.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

I, the undersigned, being elected

of the Engineering Association of New South Wales, do hereby promise that I will be governed by the Act of Incorporation of the Association, and by the Rules and By-Laws of the said Association, as they are now formed or as they may hereafter be altered, amended, or enlarged, under the powers of the said Act; and I promise to promote the objects of the said Association as far as shall be in my power, and to attend the meetings thereof as often as I conveniently can. Providing that whenever I shall signify in writing to the Secretary for the time being, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of 18

Form No. 4.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Sydney, 18 .

Sir,

I am directed by the Council of the Engineering Association of New South Wales to inform you that your subscription to the Association is two years in arrears, and in pursuance of Article 5, Section V., of the Rules and By-Laws, the Council have declared by special vote on the

day of 18 , that you have forfeited your claim in future to belong to the Association, and your name will be in consequence expunged from the register, unless payment is made previous to

But notwithstanding such forfeiture as regards the future, I am directed to call upon you for payment of your arrears, amounting to £

I am, Sir, &c.,

Form No. 5.

Balloting List for the Election of the Officers and Council.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Date

BALLOTING LIST for the Election of the Officers and Council.

Present Council.	Names proposed as Members of New Council.	Names proposed by any dissentient Member.
President.	President.	President.
Vice-President.	Vice-President.	Vice-President.
Hon. Treasurer.	Hon Treasurer.	Hon. Treasurer.
Hon. Secretary.	Hon. Secretary.	Hon. Secretary.
Members of Council.	Members of Council.	Members of Council.

If you wish to substitute any other name in place of that proposed, erase the printed name in the second column, and write opposite to it, in the third, that which you wish to substitute.

OFFICERS, 1886-87.

COUNCIL:

President.

A. C. MOUNTAIN (resigned on 9th December).

W. D. CRUICKSHANK (elected 9th December).

Vice-President.

G. A. KEY.

Hon. Secretary.

GUSTAVE FISCHER.

Hon. Treasurer.

JOHN SANDS.

Members.

WALTER SHELLSHEAR.

ROBERT POLLOCK.

H. W. KERLE.

NORMAN SELFE.

J. RICHMOND.

A. D. NELSON.

Secretary.

W. E. H. NICOLLE.

LIST OF MEMBERS.

NOVEMBER, 1887.

CORPORATE MEMBERS.

1883	Auldjo, L. C.	Mort's Dock and Engineering Works, Balmain
1886	Allen, Percy	Roads and Bridges Department, Sydney
1886	Adams, W. J.	15 Bond-street, Sydney
1873	Blacket, Owen ...	Commercial Chambers, Bond-street
1876	Boulton, George ..	Mort's Dock and Engineering Works, Balmain
1878	Bennett, Frank ...	*Evening News* Office, Sydney
1879	Bennett, C.	" Restormel," Darling Point, Sydnay
1879	Bailey, W. S.	" Gowan Brae," Cecil-street, Ashfield
1882	Brydon, R.	Chisholm-road, Auburn
1883	Brodie, D.	Harbours and Rivers Department, Sydney
1884	Bush, T. F.	Australian Gas-Light Co., Kent-street, Sydney
1885	Bagshawe, F. T. ...	Existing Lines of Railways, Sydney
1884	Burman, E. S. ...	City Surveyor's Office, Town Hall, Sydney
1885	Briggs, Samuel ...	Mort's Dock and Engineering Works, Balmain
1870	Cruickshank, W. D.	Marine Board Office, Sydney
1878	Crispin, W.	66 Harbour-street, Darling Harbour, Sydney
1880	Cracknell, E. W. ...	Bond-street Chambers, George-street, Sydney
1887	Christie, A.	88 Pitt-street, Sydney
1883	Darley, C. W. ...	Harbours and Rivers Department, Sydney
1873	Davies, Hy.	Do. do. do.
1883	Dunn, J. M.	Tattersall's Chambers, Hunter-street, Sydney
1883	Diamond, P.	52 Pitt-street, Redfern
1886	Duncan, A. J. ...	Little Collins-street, Melbourne
1886	Dickinson, H. E. ...	c/o Hunter River N.S.N. Co., Sussex-street, Sydney
1878	Edgington, J. ...	Atlas Engineering Works, Sydney
1883	Elder, James... ...	" Rocky Glen," Balmain
1870	Franki, J. P.	Mort's Dock and Engineering Works, Balmain
1870	Ferguson, T., Senr.	Do. do. do.
1876	Frost, Arthur ...	Locomotive Engineer's Office, Redfern

1886	Frost, H. P.	587 George-street, Sydney
1882	Fischer, Gustave...	Existing Lines of Railways, Sydney
1882	Finlayson, R. W. ...	H. P. Gregory and Co., 17 Pitt-street, Sydney
1885	Fitzmaurice, J. S. ...	97 Clarence-street, Sydney
1885	Farmer, W. T. ...	57 Sydney Arcade
1885	Formby, M. R. ...	Looke's Avenue, Balmain
1882	Fenwick, J.	Balmain
1885	Ford, H.	Dock Road, Balmain
1870	Grant, W.	32 Point-street, Pyrmont
1883	Grant, James	3 Point street, Pyrmont
1885	Grant, J. L.	
1882	Goodall, E.	Caroline-street, Balmain
1883	Griffin, J. G.	Australian Club, Sydney
1885	Greenwood, W. ...	"Gracombe," Croydon
1885	German, Joseph ...	7 Cohen's Buildings, Spring-street, Sydney.
1873	Howe, H. B.	Government Tramway Works, Randwick
1875	Hargrave, L.	Rushcutter's Bay Road, Sydney
1878	Humphreys, W. H.	Bond-street Chambers, George-street, Sydney
1882	Hunt, E. J.	9 Change Alley, Pitt-street, Sydney
1883	Henson, J. B.	City Engineer's Office, Town Hall, Sydney
1883	Henderson, J. B. ...	Water Supply Department, Brisbane
1883	Henderson, T. ...	
1883	Hudson, Hy.	Clyde Engineering Works, Granville
1870	Hunter, Peter ...	Newcastle S.S. Co., Lime-street, Sydney
1882	Halligan, E. M. ...	Existing Lines of Railways, Sydney
1886	Harris, R.	District Survey Office, Sydney
1877	Irons, T.	Atlas Engineering Works, Sydney.
1883	Irving, W.	Mort-street, Balmain
1882	Jones, J. Trevor ...	City Engineer, Town Hall, Sydney
1883	Joseph, F. E.	4 O'Connell-street, Sydney
1882	Kingsbury, H. H. ...	54 Margaret-street, Sydney
1881	Kopsch, G. A.	"Saxonia," Boulevarde, Petersham
1883	Kerle, H. W.	141 Pitt-street, Sydney
1884	Kidd, Hector... ...	Colonial Sugar Co., Sydney
1885	Kirwan, M. E. ...	Box 695, G.P.O., Sydney
1885	Key, G. A.	88 Pitt-street, Sydney
1885	Kendall, Robert ...	Existing Lines of Railways, Sydney
1870	Laing, J.	Snails Bay, Balmain
1885	Leahy, J. A. L. ...	263 George-street, Sydney
1883	Mountain, A. C. ...	City Surveyor, Town Hall, Melbourne

1870	Morell, G. A.... ...	156 Pitt-street, Sydney
1876	Mainwaring, M. ...	Austral Foundry, Pyrmont
1879	Moore, F.	Existing Lines of Railways, Sydney
1881	Morse, R.	Rockdale, Illawarra Railway
1883	Mackay, Angus ...	Technical College, Sydney
1883	Milne, W.	Sussex-street, Sydney
1881	McPherson, H. ...	491 Kent-street, Sydney
1877	McCredie, A.	250 Pitt-street, Sydney
1882	McCredie, G.	250 Pitt-street, Sydney
1885	Macfadyen, J. J. ...	Botany Waterworks
1885	Macdonald, A. B....	c/o Howard Smith and Sons, Melbourne
1885	Massey, G.	Post Office Chambers, Pitt-street, Sydney
1886	Marshall, A. D. ...	Marine Board Office, Circular Quay, Sydney.
1887	McKinney, H. G. ...	Athenæum Club, Sydney
1875	Nicolle, W. E. H....	Harbours and Rivers Department, Sydney
1877	Nelson, A. D.... ...	Hay-street, Darling Harbour, Sydney
1886	Noakes, W. M. ...	Wynyard Square, Sydney
1883	O'Neil, C.	200 Cumberland-street, Sydney
1873	Perdriau, H.	Balmain Engineering Works, Balmain
1878	Patterson, J. J. ...	Brumby-street, Strawberry Hills, Sydney
1881	Parry, John	Existing Lines of Railways, Sydney
1878	Pollock, Robert ...	Bulli Coal Co., 17 Bridge-street, Sydney
1873	Proctor, J.	19 George-street, Redfern
1870	Poolman, S.	Colonial Sugar Co., Sydney
1882	Parrot, T. S.	Mercantile Chambers, Pitt-street, Sydney
1885	Parkinson, W. A. ...	"Arthursleigh," William-street, Randwick
1886	Paisley, W.	Burwood
1884	Richmond, J.	Messrs. John See and Co., Sussex-street, Sydney
1886	Ritso, G. F.	G.P.O., Sydney
1886	Rhodes, Vincent ...	Clyde Engineering Works, Granville
1886	Robertson, W. F. ...	335 Pitt-street, Sydney
1886	Reeks, W.	139, Pitt-street, Sydney
1870	Scott, W....	Gov. Railway Works, Redfern
1873	Scott, R.	Gov. Railway Works, Redfern
1875	Scott, J.	24 Shepherd-street, Darlington
1885	Scott, T.	Orient S.S. Co.
1870	Selfe, Norman ...	Lloyd's Chambers, George-street, Sydney.
1882	Selfe, Hy.	Marine Board Office, Sydney
1878	Smith, H. Shaw ...	17 Pitt-street, Sydney
1873	Sands, John	Albion Engine Works, Pyrmont
1878	Sands, H. G.	Albion Engine Works, Pyrmont
1882	Schulze, Oscar ...	Hawkesbury Bridge, Peat's Ferry

1881	Shellshear, W. ...	Existing Lines of Railways, Sydney.
1882	Stewart, T.	Electric Telegraph Department, Sydney
1883	Stone, J. J.	Harbours and Rivers Department, Sydney
1884	Stables, E. C. ...	New Zealand Sugar Co., Auckland, N.Z.
1884	Smail, J. M.	Sewerage Department, Sydney
1885	Shaw, P. W.	Existing Lines of Railways, Sydney
1886	Shachan, G.	Sydney
1887	Storer, J.	163 Clarence-street, Sydney
1879	Thomson, Max ...	Existing Lines of Railways, Sydney
1885	Thomson, J. R. ...	Atlas Engineering Works, Sydney
1882	Townsend, G. W....	Colo Valley via Richmond, N.S.W.
1873	Tipping, J.	Government Railway Works, Redfern
1882	Tulloch, R.	Phœnix Works, Pyrmont
1882	Toyer, A.	*Daily Telegraph* Office, King-street, Sydney
1885	Touch, J. E.	Existing Lines of Railways, Sydney
1883	Van de Velde, C.	Royle's Chambers, Bond-street, Sydney
1886	Vale, Hy. J.	Locomotive Works, Auburn
1878	Wilson, W. G. ...	Snails Bay, Balmain
1878	Wildridge, J.... ...	Messrs. Gibbs, Bright and Co., Pitt-street, Sydney
1881	Wright, John ...	Railway Department, Sydney
1882	West, W.	Balmain Engineering Works, Balmain
1882	Walker, John ...	H.M.C.S. "Wolverine"
1883	Walsh, Fred.... ...	76 Elizabeth-street, Sydney
1883	Waugh, D.	Brisbane-street, Sydney
1884	Warren, W. H. ...	Sydney University
1885	Wells, W. S.... ...	Roads and Bridges Department, Sydney
1886	Watkins, C. E. ...	Reefton, New Zealand
1886	Wilkinson, C. T. ...	Mines Department, Sydney
1887	Walker R. B. ...	Electric Telegraph Department, Sydney

STUDENTS.

1884	Burrows, C.	Albion Engine Works, Pyrmont
1886	Cape, M. T.	Mort's Dock and Engineering Works, Balmain
1886	Edgell, R. G. ...	Do. do. do.
1887	Finch, S. W.	c/o Kenwood and Kerle, 141 Pitt-street, Sydney
1882	Laidley, R.	W. Laidley and Co., Exchange, Sydney
1884	Moffitt, W.	Locomotive Engineer's Office, Redfern
1885	Moore, G. E.... ...	Albion Engine Works, Pyrmont
1882	Nicholle, E. H. ...	Mort's Dock and Engineering Works, Balmain
1881	Owen, P. T.	Do. do. do.
1883	Stokes, S.	Drayton House, Leichhardt
1883	Woolnough, H. B.	Mort's Dock and Engineering Works, Balmain

ASSOCIATES.

1886	Ahearn, J.	"Bronte," Burwood
1886	Carron, T. P. ...	Ashfield
1887	Hordern, L.	Haymarket, Sydney

HONORARY MEMBERS.

Broderick, Hy. ...	Sydney Club, Castlereagh-street, Sydney
Bennett, W. C. ...	Engineer-in-Chief for Roads and Bridges, Sydney
Barnet, James ...	Colonial Architect, Sydney
Cracknell, E. C. ...	Superintendent Electric Telegraph Department, Sydney
Jacob, A. H.	Ashfield
Moriarty, E. O. ...	Engineer-in-Chief for Harbours and Rivers, Sydney
Poole, W. T.	Hampden House, Pitt-street, Redfern
Sutherland, John	Minister for Public Works, Sydney

DONATIONS TO THE LIBRARY.

Transactions of the American Society of Civil Engineers. Part of 1887.
Transactions of the North of England Institute of Mining and Mechanical Engineers. Vols. 35 and 36, and part of Vol. 37.
Proceedings of the Society of Engineers' Transactions for 1861 to 1863, 1865 to 1876, 1878 to 1886.
Journal of the Franklin Institute. Part of 1887.
Bulletin de la Société Vaudoise des Ingénieurs et des Architectes. Parts of 1886 and 1887.
Transactions of the American Institute of Mining Engineers. Vol. 15.
Proceedings of the Institution of Mechanical Engineers. 1887.
Library Catalogue of the Institution of Mechanical Engineers. June, 1887.
Engineering. Part of 1887.
The Sydney University Calendar. 1887.
The President's Address to the Royal Society of New South Wales. 1886.
Transactions of the Royal Society of New South Wales. Vols. 20 and 21.
Letters of Registration of Inventions, New South Wales. 1882.
Handbook of New Zealand. Hector.
Reports of Geological Explorations in New Zealand. Nos. 16, 17, 18.
Manual of New Zealand Mollusca. Hutton.
Palæontology of New Zealand. Tenison Woods.
Catalogue of Geological Exhibits. 1886. Hector.
Studies in Biology, New Zealand. No. 3.
Twenty-first and Twenty-second Annual Reports on the Colonial Museum and Laboratory, New Zealand.
Indian Engineering. Parts of Vols. 2 and 3.
The Indian Engineer. Part of Vol. 4.
Proceedings of the Royal Colonial Institute. Vol. 18.
Transactions and Proceedings of the New Zealand Institute. Vol. 19
Institution of Engineers and Shipbuilders in Scotland. 30th Session. 1886-7.
Civil and Mechanical Engineering Popularly and Socially Considered. J. W. C. Haldane, C.E. and M.E.
Statistique de l'Industrie Minérale et des Appareils à Vapeur en France et en Algerie. 1881, 2, 3, 4, 5.
Chemins de Fer Français. France Européenne et Algérie. Documents Statistiques, Lignes d'Intérêt Générale. 1881, 2, 3.
Situation des Chemins de Fer Français. 1881, 2, 3, 4, 5. With four maps.
Routes Nationales. Recensement de la Circulation en 1882. 1 vol., texte; 1 vol., atlas.
Album de Statistique Graphique. 1884-5.
Chemins de Fer Français. Documents Statistiques; Lignes d'Intérêt Local. 1881, 2, 3.
Mittheilungen aus den Koeniglichen Technischen Versuchsanstalten zu Berlin. Fuenfter Jahrgang, 1887; mit Ergaenzungsheften.

THE ENGINEERING ASSOCIATION

OF

NEW SOUTH WALES.

SESSION 1886-87.

MINUTES OF PROCEEDINGS,

ANNUAL GENERAL MEETING,

21ST OCTOBER, 1886.

WALTER SHELLSHEAR, PRESIDENT, in the Chair.

THE following candidates were balloted for and duly elected as

MEMBERS:

G. STRACHAN.
W. J. ADAMS.
R. HARRIS.
A. D. MARSHALL.

ASSOCIATE:

S. HORDERN.

The SECRETARY read the Annual Report of the Council and the Balance Sheet for the year ending 30th September, 1886, as follows :—

"The Council have the pleasure of presenting to the members on this occasion of the 16th Anniversary of the Association the following Annual Report for the past year :—

"The total number of members of all classes on the roll of the Association on the 30th September was 159, as compared with 140 at the end of the previous year. During the past year 22 names have been added to the Society, and three names have been withdrawn by resignation, which leaves a net gain of 19 members,

comprising 143 corporate members, 8 students, and 8 honorary members, so that it may fairly be considered that the Association continues to increase both in numbers and usefulness.

"The accounts for the past year having been examined by the duly appointed auditors, are now submitted for the information of members. The expenses of working a small Association such as ours, are of necessity heavy; but as the usefulness of the Society depends upon the publication and circulation of its proceedings among its members and others, it would be impossible to reduce the expenditure without seriously curtailing the utility of the Association. A resolution was moved, and carried unanimously at two successive general meetings, to alter Section V., Clause 1 of the Rules and By-laws so as to read, that "Each member shall pay *two guineas*, each associate two guineas, and each student one half-guinea per annum." The Council would express its recognition of the unanimity which actuated the members when the resolution to increase their annual subscription to two guineas was carried, by which act the financial difficulties which have hitherto beset the Association will be largely removed, and the legitimate expenditure kept within the limits of the revenue.

"By the statement of accounts attached, it will be found that the income from all sources up to the 30th September amounted to £326 15s. 9d., while the expenditure (for the year) has been £516 16s. 7d., showing that it has been necessary to incur an overdraft to meet the current expenses, the amount of which will have to be withdrawn from the Society's reserve funds.

"Endeavours have been made from time to time to secure suitable meeting rooms in a convenient position, and at a lower rental than that at present paid, and so to some extent reduce the expenditure, but after the inspection of many rooms which have been under offer to the Association, the Council have been unable, so far, to attain their object, and so have determined to remain in occupation of the present rooms.

"The Council have very great pleasure in acknowledging the useful labours of the various members who have contributed

papers during the past year, and consider it a matter for congratulation that a larger number of papers have been presented to the Association than in any previous year.

"Sixteen general meetings have been held during the year, with an average attendance of 30 members per meeting, and the following is a list of papers read and discussed:—

"In December, 1885, two papers were read by C. Van de Velde on the 'Metallurgy of Copper,' and on 'Bread-making Machinery.'

"In January, by A. L. Leahy, on 'Simultaneous Telegraphic and Telephonic Communication.'

"In February, by J. M. Smail, on 'Healthy Dwellings.'

"In March, by Norman Selfe, on 'Compressed Air and its Applications,' which was discussed at an adjourned meeting.

"In April, by W. Shellshear, on 'Breakwaters and Training Jetties,' which was also discussed at an adjourned meeting.

"Also in April, by C. Wagemann, a non-member, on 'Concentrated Solutions of Soda for Generating Steam.'

"In May, by Angus Mackay, on the 'Mechanics of Agriculture.' Also at the same meeting a paper by Henry Selfe on 'Colonial-built Harbour Steamers.'

"In June, by F. Bergin, on the 'Metallic Arch.'

"In July, by F. T. Bagshawe, on the 'Beth Process of Ice-making.'

"In August, by W. S. Bailey, on 'Economy in Steam Navigation.'

"And in September, by A. C. Mountain, on 'Notes on Portland Cement,' which was further discussed at an adjourned meeting.

"The Exhibition recently held by the Association in the Exhibition Building at Prince Alfred Park has been a matter of considerable public interest, and it is satisfactory to know that although the financial results are not equal to those of the preceding show held in 1883, there is a balance on the right side of the books. When the various accounts in connection with the matter

are all finally settled, the Executive Committee will present their report, and whatever balance remains will be transferred to the Association funds.

"The Library of the Association is not in such a satisfactory condition as might be desired, and although several important and valuable periodicals and volumes have been added during the year, there is yet room for many new standard works. It is to be hoped that the new Council will be able during the ensuing year to bestow some attention to this matter, and it is confidently anticipated, now that the proceedings are in print and about to be published, that it will lead to an interchange of volumes with some of the leading scientific societies of the world. The preparation of the Society's annual volume (which has been a work of no small labour), is an important step in the progress of the Association, and the thanks of the Association are due to the Honorary Secretary and Editor (Mr. Gustave Fischer) for the large amount of time he has spent in preparing the volume for publication.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Dr. **Account of Expenditure and Receipts for the Year ending 30th September, 1886.** **Cr.**

Expenditure.	£	s.	d.
To Rent of Room	153	3	4
,, Printing and Engraving Proceedings ...	160	8	0
,, General Printing and Binding	24	11	6
,, Periodicals	16	15	6
,, Petty Cash, including postage, stationery, advertising, and insurance ...	27	9	9
,, Annual Re-union	91	0	6
,, Secretary's Allowance	25	0	0
,, Gold and Silver Medals	6	6	0
,, New Cupboards	12	0	0
,, Exchange on Cheques	0	2	0
Total Expenditure...	£516	16	7

Receipts.	£	s.	d.	£	s.	d.
By Entrance Fees—						
21 Members at £2 2s. ...	44	2	0			
1 Student at £1 1s. ...	1	1	0			
				45	3	0
,, Annual Subscriptions ...				143	2	9
,, Annual Re-union, 1884 ...	9	12	6			
,, Do. do. 1885 ...	88	1	6			
				97	14	0
,, Rent of Rooms				19	0	0
,, Sale of Pamphlets				11	1	0
,, Excursions				0	15	0
,, Interest on Fixed Deposit ...				10	0	0
Total Receipts				326	15	9
Balance being excess of Expenditure over Receipts carried down ...				190	0	10
				£516	16	7

	£	s.	d.		£	s.	d.
To Balance brought down	190	0	10	By Balance 30th September, 1885	138	1	5
				,, Bank Overdraft	51	19	5
	£190	0	10		£190	0	10

Audited and certified by JAMES ELDER, J. B. HENSON, } Auditors.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Dr. **Balance Sheet as at 30th September, 1886, Approximate.** **Cr.**

	£	s.	d.
To Bank Overdraft	51	19	5
,, Capital of the Association at this date	715	3	10
	£767	3	3

	£	s.	d.
By Bank Deposits E. S. and A. C. Bank	311	6	0
,, Subscriptions in Arrear	66	7	3
,, Annual Re-union	19	10	0
,, Library, Drawings, Proceedings ...	300	0	0
,, Furniture and Fittings	70	0	0
	£767	3	3

Audited and certified by JAMES ELDER, J. B. HENSON, } Auditors.

The Report and Balance Sheet were unanimously adopted.

The ballot for the election of officers and members of Council for the Session 1885-86 resulted as follows:—

PRESIDENT:
A. C. MOUNTAIN.

VICE-PRESIDENT:
G. A. KEY.

HON. SECRETARY:
GUSTAVE FISCHER.

HON. TREASURER:
JOHN SANDS.

OTHER MEMBERS OF COUNCIL:

WALTER SHELLSHEAR.	NORMAN SELFE.
ROBERT POLLOCK.	J. RICHMOND.
H. W. KERLE.	A. D. NELSON.

After passing an unanimous vote of thanks to the retiring officers, the meeting terminated.

11TH NOVEMBER, 1886.

A. C. Mountain, President, in the Chair.

The PRESIDENT announced that the Council had appointed Messrs. L. Hargrave and W. E. H. Nicolle as librarian and secretary respectively.

The PRESIDENT presented a number of valuable books on engineering and scientific subjects, as awards of encouragement to those apprentices who had prepared and exhibited drawings, models, &c., at the society's late exhibition.

Mr. A. C. MOUNTAIN then addressed the meeting in the following terms, on the occasion of taking the chair at the first meeting, after his election as president:—

GENTLEMEN,—It devolves upon me, on taking the chair for the first time as President of the Engineering Association of New South Wales, to deliver a few remarks on subjects that are likely to prove of interest to members; although, with the exception of last year, when the Past President instituted the practice of delivering an address—it has not hitherto been the custom with this Association: but the fact that it is invariably done in all scientific or professional societies justifies the introduction of the practice here; whilst the opportunity thus afforded to refer in general terms to a variety of subjects bearing upon engineering work, and which are likely, more or less directly, to affect the welfare of this association, appears to my mind to be one which should be availed of—not only in the present instance, but on all future similar occasions. At the same time, I am sensible that to attempt the task of merely alluding in a very cursory manner to some of the works in our profession which mark the steady development of our country, or of touching on the still more delicate subject of the present position and probable prospects for professional men in New South Wales, is to self-impose a not light burden, and one from which I would

feel inclined to shrink, did I not have the consciousness that my audience is kindly and ready to make allowance for my shortcomings.

In the first place, it is quite impossible in a new and comparatively undeveloped country to give any narrative of great engineering feats that surprise and delight the world by their originality of conception and novelty of design, as is the case in the old world, where—year after year—the records of difficulties overcome, of fresh mastery of the powers of nature, of new discoveries in the world of science, or of the additional achievements, for the benefit and advantage of the human race, are dwelt upon by the chiefs of the great engineering societies of England, Europe and America, to the delight and instruction of their audiences. Rather is ours the case of a nation, young, vigorous and impulsive, throwing its whole energies into the actual work which has to be done, and in doing which it finds no time to waste in the quiet contemplation of patient thought so necessary for developing the faculty of invention, thus of necessity causing its work to be largely the outcome of the best and ripest experience of the old world masters. That this should be so at our present stage of growth is inevitable, and not at all to be deplored; but, as the fever heat of youth passes away, and the calm and repose of maturity begins to appear, there can be no doubt that Australia will produce her inventors and men of genius and originality in the various branches of our common profession, even as—in the course of time, and under the influences of the fostering conditions of leisure, technical culture, and opportunity—the countries of the old world have produced their great engineers and mechanics.

I propose, in a brief way, to refer to the more noticeable works in New South Wales, thus giving a general idea of the strides she is taking in the race of progress; after which I would wish to make a few remarks on the state of the engineering profession in the colony at the present time, the prospects and inducements for men to follow the profession in the future, and the advantages and opportunities that are afforded to those desirous of entering upon that career.

In the first instance it is well to remember that the peculiar conditions of Australia were such as to render it inevitable that, for many years at all events, the most important engineering works of almost every description, should be carried out by the State; thus *Roads*, closely followed by *Railways*, were constructed in order to open up the country and afford facilities to the inhabitants to dispose of their produce in its different markets; *Bridges* to span the rivers and streams, thereby shortening and rendering safe such means of communication; *Breakwaters and Jetties* to form safe havens for our shipping, and *Docks* to repair same; *Dredging* and other *River Improvements* to render our larger steamers subservient to the needs of commerce; the *Electric Telegraph* to transmit our message, literally "with lightning speed" were soon undertaken by the Government; whilst following in their wake, and continuing up to the present time, are the various works commenced for *Water-Supply* and *Sewerage* (rendered necessary by the growth of population in our larger cities and towns); *Fortifications*, *Hydraulic Cranes*, and other appliances for shipping coal; and now, in all probability, *Irrigation*, all of which have been, and are being, executed under the direction and control of engineers employed by the State, or by some local public body, instead of being, as is the case in older and more populous communities, largely carried out by private enterprise. It will thus be seen that the scope for private engineers is, comparatively speaking, very limited, whether considered from the standpoint of a civil or mechanical speciality.

This natural disadvantage has been increased during the past few years by the severe depression in all branches of commerce and industry under which this colony has laboured, a depression primarily due to the trying seasons to which it has been subjected, and also to the universal stagnation in trade which has been reported from other countries. Whether the evils thus caused have been aggravated or lessened by the policy of our legislators—whether prudence wisdom and true patriotism are the motives which guide their deliberations—are questions on which I will not venture to express an opinion in this place; but will content

myself with remarking, with deep regret, that the present condition of engineers of all grades and classes in this community, outside of those holding public or official positions, is distressing in the extreme, from whatever cause arrising; and that probably, at no period of our history has there been a larger number of men connected with engineering work (either as professional men, designers, or operatives) unable to obtain employment. It is also a significant fact that all our private engineering firms are compelled to reduce the number of their hands to a minimum, and are doing very little business; whilst in the case of those professional men who have secured engagements, many have been forced to accept a rate of remuneration that would be refused by a labourer! We can only hope that under more favourable auspices—with better seasons, and a general improvement in commerce and manufactures—we may soon find prosperity replace the present anxious period of depression.

I now propose, in the briefest possible manner, to refer to some of the principal works in the Colony, naturally commencing first with—

Railways.—Probably everyone here present is aware that the first railway in Australia (Sydney to Parramatta, a length of 14 miles) was opened in 1855, and that the construction of our present railway system was slowly carried on until in 1876 there were 509 miles open for traffic. That 21 years should have elapsed whilst executing this work was due to many other reasons than engineering ones; although, as this work included the crossing of the Blue Mountain Range, in the case of the both Southern, Western, and Northern Lines, and involved the construction of the famous Zig-Zag, and the driving of several long tunnels, there was sufficient difficulty to render the work both formidable and tedious. During the past ten years the extensions have been much more rapid, there being, at the present time, about 1,790 miles of railway open in the colony, and through communication established between Sydney, Melbourne, and Adelaide; whilst Brisbane will, in the course, probably of one or two years, be also linked to Sydney with the "iron band." Undoubtedly

the most interesting feature in connection with our railway works will be the new bridge now being erected across the Hawkesbury River, by the Union Bridge Company of New York, under the direction of the Engineer in Chief for Railways of New South Wales. This bridge is designed of seven openings, each of 415 feet, resting on steel piers, each of which forms a single caisson 52ft. x 24ft. at base, with flat sides and rounded ends, on which a pair of cylinders are to be built above water level to carry the girders.

The especial interest attaching to this bridge will, of course, be the successful sinking of the caissons, which, in some instances, may have to be sunk as deep as 170 feet below water level, in order to ensure a good foundation, and the accomplishment of which feat will be watched with interest by all engineers,—in view of the fact that in this particular (viz.: the depth to which the caissons will have to be sunk in order to obtain a sound bottom) the bridge will be *unique*. It is designed to carry a double line, and will be the longest bridge in the Southern Hemisphere, being over 2,900 feet in length. The girders are to be of the usual American lattice type, with pin fastenings for eye-bars and struts, rivets elsewhere.

An illustration of the American whipple truss, with pin fastenings is also to be seen in the new iron bridge over Iron Cove Creek (between Petersham and Summer Hill) which was completed a few days since by sliding the half width of the bridge intended for the up-line, from a temporary framing on which the traffic had been carried whilst portion of the old stone viaduct was being demolished into its permanent position on the new brick piers. As we are to have a paper on this very well executed alteration (which was only about five hours in execution, and which it was my privilege to witness) I shall not here do more than say that the bridge was designed by Mr. Max Thomson, A.M. Inst., C.E., under the supervision of Mr. Cowdery, Engineer for Existing Lines; whilst Mr. Kendall, Assistant Engineer, superintended its erection and subsequent change of position.

Roads and Bridges.—I quote from Prof. Warren, A.M.I.C.E., the following remarks on a bridge now being erected over the

Paterson River, from an official report of an inspection made by him of the superstructure in the yard of the contractors, Messrs. D. and W. Robertson, of this city, as illustrating probably the best type of bridge yet designed by this large and important department, both as regards economy of material and suitability of construction. "The bridge consists of two lattice main girders, continuous over three openings of 91 feet, 119 feet, and 91 feet respectively, placed 23 feet apart from centre to centre, and each forming a continuous girder 303 feet long, resting on masonry abutments and extending over two intermediate cylinder piers. These girders are 8 feet in depth and parallel throughout their length excepting at the ends where they are curved to the form of an ellipse; they are fixed to the S.E. abutment, and rest upon expansion bearings upon the other abutments, as well as over the two intermediate piers. The booms are trough-shaped and connected with double lattice web; the bottom booms being connected together with horizontal wind-bracing. * * * The workmanship is equal to the best imported bridge work. The dead load in the deck and cross-girders is 25 cwt. per foot run; the weight of main girder is 8 cwt. per foot run. The bridge has been designed to carry a live load of 84lbs. per superficial foot, as well as the dead load. The superstructure weighs 0·75 tons per foot run; the total weight of iron work in superstructure and piers being about 300 tons, whilst the total cost amounts to £31 7s. per foot run of bridge. The bridge is very light for the loads it is calculated to carry. At the same time its lateral strength to resist wind, pressure and vibrations due to rolling loads, as well as its vertical carrying strength, is fully up to the heaviest traffic that may ever be expected to pass over it. The expansion arrangements are worthy of special notice, for it is well knownthat the provisions in this respect in most of the bridges both in England and the colonies are, to say the least, defective and uncertain. As the stress produced by non-expansion may in many cases exceed those due to the heaviest traffic, it is most important to interfere as little as possible with the free expansion of the bridge. In this case the expansion is reduced to a certainty, as the rollers are 2 feet in diameter, and the load per lineal inch does

not exceed 13 cwt. This arrangement is the invention of Mr. J. Alex. Macdonald, A.M.I.C.E., M.I.M.E., who has also designed the bridge under the supervision of Mr. Wm. C. Bennett, M. Inst., C.E., Engineer-in-Chief for Roads and Bridges"

This report is especially of interest as being made on a bridge that has been both designed and manufactured in the colony; and which after being subjected to the critical inspection of our engineering profession, passed through the ordeal in so satisfactory a manner.

Metropolitan Sewerage.—In connection with the Roads and Bridges Department, the construction of a sewerage system to deal with the drainage of the greater portion of the city and suburbs is being carried out, and is now approaching completion. As the chief aim of this work will be to intercept, as far as practicable, the sewage which now discharges into and pollutes the harbour, by sending portion of it out to the ocean and utilizing a part for the purpose of forming a sewage farm below Cook's River, it will effect a much needed improvement in the sanitary condition of the metropolis.

The trunk sewer, designed to drain the northern district, extends from the centre of the city easterly to the coast line at Bondi, being a length of $4\frac{1}{4}$ miles: this is chiefly driven through solid rock, except near the coast, where drift sand and water (requiring much ingenuity in overcoming) were encountered. This sewer is now completed, and the construction of several branch intercepting sewers is being proceeded with. The southern and south-western district will be drained by a main sewer starting in Surry Hills, and running southerly across Cook's River (crossed by means of an inverted syphon) on to a sandy tract of land, now being laid out as a sewage farm. The main sewer is now finished, and the syphon is nearly so, although the execution of this work presented more than ordinary difficulties (owing to the bad bottom in part of the river bed), which delayed the works considerably. There will still be a great deal of work to do in gradually connecting the existing sewers of the city with the new scheme, and many knotty questions to settle; but there is little doubt but that the greater half of the work is now completed.

Water Supply.—The very extensive scheme for the supply of water to the metropolitan area is also one which has occasioned a considerable amount of public attention, both from the magnitude of the works and the necessarily lengthy duration of the contracts into which it is divided. As the temporary supply scheme, constructed by Messrs. Hudson Brothers for the Government, has already tapped the permanent works near Guildford, and delivered water to the city, it may be said (in a measure) that this large scheme is now approaching completion.

Commencing at the Pheasant's Nest (a point about 63 miles from Sydney by the line of the conduit), the water is carried through tunnels and open masonry channels to the storage reservoir now in course of construction at Prospect, which will be undoubtedly the largest artificial lake in Australia, covering, as it will when full, about two square miles, and calculated to contain (*vide* Report of Commission on Water Supply) an available storage of about 7,000 million gallons, at a level of 195 feet above sea-level. From this reservoir it is intended to bring the water, partly by wrought and partly by cast-iron pipes, into the Crown Street Reservoir, supplying, *en route*, the new Circular Service Reservoir just completed at Petersham. The whole of this essentially national undertaking has been carried out under the direction of Mr. E. O. Moriarty, M. Inst., C.E., engineer in chief for harbours and rivers; who is, in addition, providing schemes of water supply for several of our inland towns (particularly Newcastle and Maitland, where very complete pumping engines are erected with this object). The new graving dock at Cockatoo Island, and various works of harbour improvement, also the very excellent hydraulic cranes at Bullock Island, for the speedy shipment of coal, should not be omitted when dealing with the important work entrusted to this department.

With reference to the maintenance and extension of water mains and sewers under the control of the municipality of the city, I find from the report of the City Engineer that, of water mains nearly 20 miles were laid during the last year in the way of extensions; and that the sewers of the city, large and small, comprise a length of 60 miles.

Electric Telegraph.—Mr. E. C. Cracknell, M.I.C.E., informs me that the extension of telegraphic communication has been such that there are now no less than 19,864 miles of wire in use, and 2,625,992 messages transmitted last year. With regard to electric lighting, installations are now running at the Railway Station, Parliament Houses, Randwick Tram Shed, and at both Circular Quay and Cowper Wharf.

As it is not long since the members of this association listened to a paper descriptive of the improvements that had been effected in paving the main thorough-fares of this city with wood, and also with basaltic stone, no further reference to this subject is needed here, beyond the remark that there are now about 207,000 square yards of carriage-ways paved with wood, and 45,000 square yards of cube-sett paving now completed; whilst money has been voted for at least half as much more as the area already finished: also, that after 6 years' experience of the Colonial hard-wood, its durability is undoubted, as the cost of maintaining the wood roads during that period has not exceeded one-half per cent. per annum on the prime cost. The slipperiness of the wood during wet or greasy weather is counteracted by spreading sand over the road, which is now being partly done by means of Garratt's "sand distributers," an ingenious invention imported from London, which will soon entirely supersede the manual work both in point of efficiency and cost.

The grave question of disposal of house refuse, etc., which affects the sanitary condition of a city so much, has not yet been finally dealt with, although some exhaustive reports on the subject have been submitted to the authorities in favour of treatment by fire, somewhat similar in character to the processes adopted in Leeds, London, and other English cities. It cannot be long before some such system will have to be introduced in Sydney, as at the present time it is becoming a serious question to know what to do with all the various and offensive "waste products" of a populous city.

Gas Works.—I should not omit to mention the very fine works recently constructed by Mr. T. J. Bush, the engineer to the Aus-

tralian Gas Light Coy., at Mortlake, Parramatta River, as the nucleus for a new establishment in the event of the Company leaving their present works in Kent-street. The enormous gas-holder, rising 112 feet above the ground level, and about 180 feet in diameter, and the elaborate arrangement of elevated wharf and railway, are not more interesting than the beautiful mechanical appliances that "charge" and "draw" the retorts by means of compressed air. As the members of the Association will shortly visit these admirable works, I shall not dwell at length on their description.

I regret that the time at my disposal has not enabled me to obtain information respecting any works of note of especial interest that may have been executed in the private engineering establishments, particularly in reference to marine work; but my friend, our worthy Vice-President, will be able to supply that want most fully, and I am sure will do so ere long. I must not omit to direct attention, however, to the very bold, and apparently successful jetty which one of our members (Mr. H. W. Kerle, C.E.), has designed and is now constructing on the open coast line, for the North Illawarra Coal Mining Company. The method of securing the piles to the rock bottom, and the system of anchoring the whole jetty so that it will withstand the force of the waves, are well worthy of study; and it will also be a subject of interest to observe its action in resisting the mighty force of the ocean in such an unprotected site. A detailed description of the work will soon be presented to this Association by the designer in the shape of a paper, so that I will forbear further reference to this work.

Whilst thus briefly tracing a few of the works of the engineer that have been carried out in this colony, in order to illustrate its progress in civilization, it would be wrong for me to omit reference to the thorough and systematic facilities for instruction in all the various branches of the profession that are now placed at the disposal of students of all classes and positions (facilities that I regret to say were not in my own earlier days), and which are probably equal in completeness of detail and extent of range, to the opportunities afforded to the youth of any country.

First of all stands the Engineering School of the University of Sydney, whose graduates are required to pass through a complete theoretical training in a course which has been specially arranged to qualify them for all the duties of an engineer. The course extends over three years (including one year in arts), and consists of lectures and practical work in such subjects as Physics, Chemistry, and in the sciences which bear more or less upon engineering. The students are also taught the use of the various instruments used in surveying and setting out engineering work—the University grounds being well suited for the practical teaching of the subject.

Instruction is also given in designing and preparing working drawings and specifications of structures and machinery. There is a laboratory attached to the School, which is fitted with typical examples of machine tools, a pair of horizontal engines, a Brush dynamo, and a powerful and accurate testing machine. The Engineering Lecture Rooms are provided with a large and complete collection of models and parts of machines and structures, diagrams, drawings, photographs, and a good technical library. In the laboratory the student receives practical instruction in the various processes involved in the preparation of materials used in the arts of construction, the quantitative determination of the efficiencies of prime movers and machines, and the testing of the strength and other properties of materials used in engineering and architecture.

The total cost to a student (including all fees), who graduates in this course, amounts to £111 4s.

The Sydney Technical College is an Institution supported by the State, which is also doing really valuable work in educating a large number of our young men who are engaged during the day in learning their various trades. The College provides instruction, by means of lectures and laboratory work, in the various sciences, as well as practical instructions in a variety of important trades, among which may be noticed boiler-making, pattern-making, the fitting and turning classes; also, brick-setting, masonry, and joiners' classes. Instruction in mechanical drawing is also given; and a most complete set of models of machinery and general constructive work is at the service of the different lecturers.

It will thus be seen that the machinery of instruction provided for men who aim at becoming professional engineers (equally with those who simply desire to attain excellence in the particular trade connected with engineering in which they are engaged) is ample and thorough; the matter for surprise is therefore that it is not more largely availed of by the public, especially in connection with the more strictly scientific course of the University. Considering the length of the course and the variety and quality of the instruction imparted, the terms can hardly be thought to be excessive; what, then, is the reason that, whilst the schools of law and medicine are well attended, so few students are seen in the engineering school? It must be conceded, I think, that the only answer to this question is that the prospects are not such as to induce young men (who are, naturally, desirous to obtain some assurance of at least a respectable and comfortable position in life) to sacrifice for them the time, money, and prolonged mental effort which is involved in obtaining a degree. The State has acted liberally in thus providing means of instruction of the most advanced character for aspirants to the various branches of engineering; but it has stopped at that point, inasmuch as no provision has been made for drafting off any of the successful students into Government employment; although, as I previously remarked, all the most important engineering works are in the hands, and under the control of the State. It is a remarkable fact that the Civil Service Act apparently ignores this diploma, and thus an incalculable injury is likely to accrue to scientific engineering in this colony. There can be no doubt of the superiority of the regular course of study in qualifying young men to enter practically on the work of their profession, as compared with a system of pupilage under which none but the few enthusiasts after knowledge who are prepared, with self-denial, to glean with difficulty their information for themselves, are likely to succeed in their career—for how can these men hope to compete in the future, as far as useful knowledge is concerned, with those who have received as a groundwork a thoroughly scientific and practical training?

With the existing advantages as above described, it would certainly be a most desirable step for the Government to take, if a system of competitive examinations were established, whereby it could be ascertained if a candidate possessed natural aptitude, as well as a knowledge of the first principles that underlie the practice of engineering, before appointing him to a position for which the scope of his talents might render him unsuitable, and the duties of which would therefore be discharged in an imperfect and perfunctory manner.

Such a mode of selecting pupils would certainly be the means of securing those most likely to prove of use to the country, and to rise ultimately to some distinction in their profession; whilst it would also be an effectual death-blow to political patronage, under the shadow of which mediocrity alone appears to flourish! With engineering, however, it should be our aim never to forget the lofty standard and ideals that have been raised by many of its most distinguished members when defining its scope and objects, in order that all of us—each in his humble way—may contribute something towards their realization. As illustrative of this view of the subject, I cannot resist quoting from the conclusion of an admirable address delivered in 1878 by Mr. John (now Sir) Frederick Bateman, President, to the Members of the Inst. C.E.

"It may with proper pride be said by engineers that there is no body of men to whom such large sums of money are entrusted, or on whose honesty and judgemnt so much depends. * * The responsibility of the engineer is great. Arduous and difficult duties are often placed upon him. He has almost uncontrolled command of money. He is generally the arbitrator in all questions of dispute between employer and the employed. His integrity, honesty and independence should be above all suspicion. He should lean neither to the one side nor the other, and his judgments should be so clearly those of knowledge and equity, that they should be entitled to as much respect as those of a Judge on the bench."

It is indeed a matter for just pride that, as a rule, the whole of the engineers intrusted in this colony with important works,

however much the fierce light of public criticism may beat upon their actions, are able to show to the world that the above is not over-drawn or an imaginative picture, but a truthful representation of the qualities that are expected, and found in our leading professional men.

The long-talked of Local Government Bill, which is daily becoming more and more a necessity, should afford an opportunity to the Government for insisting on the employment of competent men in the preparation of plans and specifications for the various works of construction that will be necessary in the different districts; this would at once open up a career to those young men who have acquired the necessary knowledge, and who have been hitherto unable to make it of practical use in the daily work of life. If it is necessary for lawyers, doctors, and land surveyors to show, by examination or diploma, that they are qualified to undertake the practice of their respective vocations, it is surely not unreasonable to demand some assurance of competence from the engineer to whom may be entrusted at any time the designing of works, on which, for want of sufficient skill, thousands of pounds may be squandered; and which, for the same reason, may even be the cause of injury and death to the public.

There is nothing in these suggestions of a revolutionary tendency, nor of a character to cause alarm to those who—having been for years practically solving the very problems that the students learn from books and by theory—are conscious that they are beyond the time for competitive examinations, and who yet intuitively feel that they know their work, and can do it well. To propose examinations to such men, or indeed to any man who has given evidence of the fact that he is a competent engineer by the works he has carried out, would not only be unjust, but most injudicious, and should not be thought of; but for the youths entering on a profession which should certainly be as honorable and noble a pursuit as any of the "learned" professions, it is desirable, in the true interests of engineering, that every educational opportunity should be seized in order that the very best material may be selected.

One word more. As it would be desirable to obtain a general and thorough grounding in the principles of mechanical law and of the forces of matter, which a liberal education can alone supply for each student who aspires to become an engineer, let it also be remembered that the same liberal training acts in another way also by enlarging the mind, expanding the heart, and inculcating those principles of honorable and courteous intercourse which go to form the *etiquette* of all professions, in the absence of which the most capable and learned man yet lacks *something*—indefinable, impalpable, it is true, but still a reality, for its subtle touch, when present, creates the vast distinction between a *cultured* and a merely *clever* man! If I have dwelt at rather great length on this subject of theoretical and scholastic training, it is because I conceive it to be all-important to the young engineer, and because I see the opportunity now offered to all hard-working students to take such a draught of the cup of knowledge as would have been quaffed with avidity by many here present this evening, had such an opportunity presented itself to them in their youthful days.

And now I should like to make a few remarks upon the Association in which we are all interested, and whose President I have the honor to be at the present time. Founded in the year 1870, by a body of about twenty-five Mechanical Engineers (many of them young men, and apprentices), who resolved at a meeting held on the 24th September of that year, that it was desirable to establish "an Association for the discussion of subjects of interest in Mechanical Engineering; for watching the progress of mechanical arts in other countries; and ascertaining its adaptability to the wants of this country." The Association was virtually formed on the 12th October, 1871, when it showed a member-roll of about sixty members, and was given the name it still bears,—"*The Engineering Association of New South Wales.*" This society gradually progressed and extended the sphere of operations originally contemplated that, in the year 1884, it submitted an application to Parliament for recognition as a body entitled to represent in New South Wales the profession of Engineering (both Civil and Mechanical), and obtained from the legislature that

Charter of Incorporation under which we now work, which establishes the Association as a corporate body duly recognized by law, and thereby bestows certain powers and privileges that will—if judiciously exercised—enable its members to make its future career prosperous and illustrious.

As I happen to know that the comparative youth of our Association, and the fact that its list of members is small as compared with the large societies of England, has been the reason why some engineers in Sydney (who belong to one or other of these societies), have refrained from joining our ranks, and who thereby imagine that it would be hardly consonant with their dignity to belong to us, I am tempted here to quote from an interesting description of the early days of the *Institution of Civil Engineers of England* given by Mr. (now Sir John) Fowler, in his address in 1866 *(vol. 25, page 223, Min. Prodgs. Inst. C.E.)*, as an illustration of how impossible it is to judge of the future development of any organization from its size or importance during its stages of early growth.

Mr. Fowler said :—"The origin of the Institution was very humble. About the year 1816, Mr. Henry Robinson Palmer, who was then articled to Mr. Bryan Donkin, suggested to Mr. Joshua Field the idea of forming a Society of Young Engineers for their mutual improvement in Mechanical and Engineering Science. The earliest members were Mr. Palmer, Mr. Field, and Mr. William Maudesley, to whom was shortly added Mr. James A. Shovell. When the society was constitued, on January 2nd, 1818, these six young men were joined by two others, Mr. Thomas Maudeslay and Mr. John T. Lethbridge, Mr. James Jones acting as secretary, *and during the remainder of that year there was no increase in the uumber, and there were only three additional members in* 1819. In the following year, when Telford became President, there were thirty-two elections. At the end of 1822, when the institution had been established five years, there had been fifty-four elections." * * * * * *

At the close of 1836, when the institution had existed nineteen years, the number of members of all classes who had been

elected was 369, and the number of those still remaining on the books was 252, or about five-seventh of those elected."

When we constrast these humble beginnings with the position of that truly influential institution at the present time, possessing (according to the list for June, 1886), 4,884 members of all classes; having a splendid library, lecture-theatre and offices; publishing the whole of the papers and proceedings of its body, and distributing the same amongst its members in all parts of the earth; whilst also making provision for special lectures on technical and scientific subjects by men of eminence in each—it must surely strike the thoughtful mind that—in a much smaller degree certainly, but in a somewhat similar way should our own Association progress, if those men will come forward and lend their hands to increase our usefulness and capacity for good, who now stand selfishly aloof and declare that *our* business is none of their concern!

Although, as is thus admitted, it cannot be urged that we have yet attained such general support and encouragement from the numerous members of both branches of the profession as the Association has a right to expect (and as it will undoubtedly command before many years elapse), I yet venture to congratulate the members upon the progress already achieved in the hope that it will stimulate them to further efforts in the interest of the Association, in order that it may, ere long, actually become a potent factor in the advancement and elevation of our profession in this colony, and also a valued and respected body amongst kindred societies in other parts of the world. The fact that amongst our ranks we now number representative men from nearly every branch of Engineering, that the Association possesses the necessary Parliamentary Charter recognising its station and giving it all requisite powers for the transaction of its business and management of its own affairs, are but small reasons (in my humble opinion) why I should recommend it to the favourable consideration of all Engineers who do not yet belong to it, in comparision with the evident need that exists for some such organization in which mutual support, sympathy, and advice may

be possible amongst Engineers, and where—simply from the *prestige* and influence which attaches to a duly recognized body of men over that possessed by an individual—the legitimate claims of our profession may be brought forcibly, yet with dignity, before the notice of the public, should occassion require.

I earnestly hope that in thus outlining the aims and aspirations of the Association, my meaning may not be misunderstood; no one could deprecate more strenously than myself anything at all approaching to undue interference with laws and regulations of the country, whether exercised by public bodies or private individuals, so long as they are justly and reasonably interpreted; nor under our free democratic institutions should anything of the kind be needed. Still it is for every man to consider whether the promotion of the interests of our profession cannot be fostered by community of sentiment, brotherly feeling and action, rather than by the isolated (and necessarily spasmodic and ineffectual) efforts of individuals.

Independently of these ideals, it will be the constant endeavor of our body to encourage a taste for study amongst its junior members, and to promote a healthy spirit of emulation by offering rewards for papers, drawings, models, or other work of sufficient merit to justify recognition.

With motives such as these I feel convinced that the *Engineering Association of New South Wales* will not fail to prosper and do good work; strong in the consciousness of being engaged in a good cause, untainted by selfish aims, petty strife, or ignoble ambitions!

In conclusion, permit me again to thank the members for the honor they paid me this year, as their President, as well as for the consideration and attention they have been good enough to accord to this rather lengthy address.

9th DECEMBER.

G. A. KEY, VICE-PRESIDENT, in the chair.

THE following candidate was balloted for and duly elected as

ASSOCIATE:
JOHN AHEARN.

The SECRETARY read a letter received from Mr. Mountain, stating that as he had left Sydney to permanently reside in Melbourne, he, with much regret, was obliged to resign his position as President.

Resolved,—"That Mr. Mountain's resignation be accepted, and that he be thanked for the interest he had always manifested in the Society's welfare."

A communication from the Council was read, recommending that Mr. W. D. Cruickshank be elected President for the remainder of the session, *vice* Mountain resigned.

This proposal met with the unanimous approval of the members, and on Mr. Key vacating the chair in favor of the newly elected President,

Mr. Cruickshank briefly referred to the circumstances leading to his appointment and returned thanks.

The following paper was then read by Mr. G. A. Key, in the absence of the author:—

SOME REMARKS ON COMBUSTION.

With refererence to the consumption of fuel in ordinary steam boiler furnaces, and to the prevention of smoke.

By E. C. Stables.

INTRODUCTION.

At the present time steam power as applied to almost innumerable purposes, in some form or other, is undoubtedly the most potent agent in forwarding, or even rendering possible, the remarkable progress evident in almost every branch of human industry, and one can hardly realise how universal the dependence on this motive power has become.

Perhaps no more vivid picture of world-wide stagnation and paralysis could be imagined, than that if on a certain date, steam could no longer be produced, and that the giant who ran the factories, and propelled trains and steamships, "annihilating time and distance," was no longer available?

Since the days of Watt an immense amount of study and thought has been given to the perfecting of the steam engine and its boiler, especially during the last few years. The introduction of the "compound engine," and still more recently of the triple and quadruple cylinders, mark distinct eras in the history of the steam engine.

Much thought and talent have been devoted to secure the economical use of steam which is shown by the many improvements in valve gears, &c., while comparatively much less—but still a large amount—of attention has been devoted to the boiler.

That great progress has been made is evident in comparing the common performance of modern steam machinery, in developing one I.H.P. from 1½ lb. of coal per hour, with the former extravagant consumption of fuel; yet, chiefly owing to the competition and the prevailing depression of trade, when only the most economical machinery can be made to pay, still greater economy is continually striven for.

The majority of mechanical engineers, who have charge of boilers and engines, either afloat or ashore, may never be called upon to design either the one or the other, their province evidently being to work the machinery, with which they are entrusted, to the greatest advantage.

The attainment of economy in the production and use of steam, is *evidently based* on the prerequisite perfect and complete combustion of the fuel liberating *all* the heat contained in it, and without attention to this point, no amount of care bestowed *afterwards*, in attempting to secure the thorough absorption by the boiler of the heat generated, or of economy in the use of the steam after reaching the engines, can lead to success.

The writer believes that, notwithstanding the many excellent works published on the chemistry of combustion, that this subject is perhaps *less* studied or understood by many of his brother *working* mechanical engineers than any other branch of their duties. The writer would therefore draw attention, in this paper, to the conditions which must be observed in order to attain "perfect combustion," accompanied by the "prevention of smoke."

Undoubtedly many engineers and firemen have, by dint of long experience, attained great skill in the management of furnaces, without any study of chemistry, yet probably some slight primary knowledge of a few of the plain facts of chemistry might have saved, in such instances, some blind laborious experimenting; for a person working in the dark, without the guidance of theory, is heavily handicapped, and must take many wrong steps.

What is combustion?

Chemists teach that it is simply energetic chemical combination, consisting in the union of the combustible with oxygen. That the amount of energy developed is constant for the same combustible, and is in each case exactly proportional to the amount of fuel burnt; also, that the intensity of the effect depends on the rapidity of the combustion.

The *oxygen* required for the above combination, for all practical purposes (except in the laboratory or in explosives) is, of course, derived from the atmosphere, which, as is well-known, consists of oxygen 21 parts, and nitrogen 79 parts, by volume. The inert nitrogen has no effect upon combustion, except indirectly, by diluting the oxygen, thus hindering its access and union with the combustible; thus greatly increasing the difficulties which, in ordinary practice, attend the proper supply of oxygen to furnaces, by the large increase in volume of the air or gas to be dealt with before, and especially after, combustion.

Lights are extinguished when the proportion of nitrogen in the air is increased by from 5 to 8 per cent., and at the latter point suffocation ensues.

Amongst the variety of combustibles in the Australian colonies, perhaps Newcastle (N.S.W.) co-operative coal may be considered as a fair representative of the fuel in most general use.

This coal has a specific gravity of about 1.3, and after passing through a retort gives from 66 to 67 per cent. of coke, and 33 to 34 per cent. of volatile matter.

Of the volatile matter about 7000 cubic feet per ton of coal, weighing perhaps 245 lbs., remains as permanent illuminating gas; the balance, after condensation appearing as ammoniacal liquor, about 238 lbs.; and tar about 140 lbs., consisting chiefly of liquid hydro-carbons. Of course no condensation of this part of the volatile matter would take place in boiler furnaces.

The ash being from 11 to 12 per cent. of the weight of the coal, when deducted from the percentage of coke, leaves 55 per cent., which may be considered as nearly pure carbon. In ordinary good boiler practice each pound of coal evaporates about 7 lbs. of water.

This coal deteriorates very slowly, and does not apparently suffer as much from exposure to the weather as most kinds of coal, especially the lighter varieties of New Zealand coals.

Having thus briefly touched on the principal components of the combination desired, viz., the union of the carbon and hydrogen with oxygen, the behaviour of the coal when in the furnace may be noticed.

When a fresh charge of coal is put into a furnace on the top of a fire already burned down clear, the first effect is of course partially to damp or smother the fire, especially if, as is usually the case, the green charge is too heavy. Heat is abstracted for the first few moments by the inrush of cold air, and by the warming and drying of the fresh coal, which is perhaps 2,000 degs, F. lower than the previous temperature of the incandescent fuel; but the chief absorption of heat is due to heat being taken up and becoming latent in generating gas from the fresh coal, just as the heat absorbed by the retorts in making gas is used in overcoming molecular attractions, or separating the molecules farther asunder. And it is well known practically in gas works that the coals which give off larger quantities of gas take up more heat in the retorts.

The first effect then of the introduction of a fresh charge of coal into a furnace is to check the development of heat, especially if small coal—lying closer and exposing more surface in proportion to its weight—is used. Thus in cases of very sudden emergency, such as shortness of water, or the crown of a furnace coming down, it may be wiser to smother the fire with green coal or ashes, rather than to attempt to draw the fire at once, for if the fire is heavy the disturbing generates for the time more intense radiant heat, rendering the drawing of the fire both a slow and dangerous process.

After the generation and ignition of the gas from the fresh coal is fairly started, sufficient heat should be given off by the flame—if the requisite oxygen is present—to keep up the gas-making process without abstracting further heat from the incandescent fuel on the bars, just as the heat of a kerosene lamp flame vapourizes and gasifies the oil which supports it.

Besides the volatile part of the coal under consideration, over half of its weight remains incandescent on the furnace bars, and being in a solid state as fixed carbon or coke, the combustion or "union with the oxygen" of this part of the fuel is less rapid than that of the gaseous portion, just as the sweetening of water would be less rapid if a hard lump of sugar were placed in it than if sweet water were added.

J. P. Cooke — Professor of Chemistry in Harvard University—says: "Since carbon, in all its forms, is non-volatile, the molecules of the charcoal cannot leave the solid lumps. They do not, therefore, go half way to meet the oxygen molecules (as the gas molecules do), but simply receive those which are driven against the coals. Hence the process depends on the activity of the oxygen-molecules alone, and, since the number of these molecules which can reach the combustible in a given time is limited by the extent of its surface, it is evident that,—we should greatly increase the rapidity of the combustion by breaking up the lumps, and thus increasing the surface in contact with the gas (oxygen)."

The conversion of the fuel into powder, or further into the gaseous state, is but the partial or complete "breaking up of the lumps."

The general adoption of Siemen's gazogene for the preliminary conversion of the *whole* of the fuel into the gaseous state, greatly as it simplifies and perfects the operations of the furnace, cannot be anticipated for ordinary boiler purposes, as, unfortunately, the apparatus is comparatively cumbrous and the process also, the fuel in the producer being converted apparently at only about one-tenth of the rate of combustion in an ordinary furnace. The writer has recently witnessed the non-success of an experimental gazogene owing to an over-estimate of the rate of conversion.

Oxygen unites with the carbon, or coke, in two proportions: Either two molecules of oxygen unite with one of carbon, forming carbonic di-oxide, otherwise named carbonic acid or carbonic anhydride CO_2, or, if the supply of air is deficient, only one molecule of oxygen unites with each molecule of carbon, thus forming carbonic acid CO.

But it must be remembered that, if the carbonic di-oxide first formed passes again through incandescent coke—as in a thick fire—one of the two molecules of oxygen seizes on another molecule of carbon forming a second volume of the oxide. Thus if the carbon is suffered to pass away to the chimney in the form of oxide half its value as fuel must be lost, and as carbonic oxide is an invisible gas the loss may not be suspected.

The atomic or combining weights of the carbon and oxygen which form the desired oxide are respectively 12 and 32, or 2⅔rds of oxygen to one of carbon, and as oxygen constitutes only ⅕th part of the atmosphere, 5 times that amount, or 13⅓rd lbs. of air, must be required per pound of carbon. Assuming that the coal under consideration contains 55 per cent. of pure solid carbon in the coke; 7⅓rd lbs. of air would therefore be required for the complete combustion of the coke from each pound of coal. The permanent gas—estimated at 7,000 cubic feet per ton of coal at, say, 80 deg. F., or 3⅓th cubic feet per pound of coal—requires for entire combustion 3 times its own bulk of oxygen; the gas from 1 lb. of coal will thus require 3⅓rd lbs. of air. The tar, consisting of condensed hydro-carbons (about 140 lbs. of tar being made per ton of coal charged into retorts), would probably require about another pound of air, amounting altogether to about 11⅔rd lbs. weight, or 170 cubic feet of air at, say, 80 deg. F. per pound of coal.

Tar, weight for weight, is usually considered to have about 1½ times the heating power of coke, and 20 cubic feet of ordinary coal gas are equal to 1 lb. of coal as fuel burnt in a boiler furnace.

Coal gas is only explosive or capable of combustion when it is mixed with air in various proportions; the most explosive mixture is that of one volume of gas to 8 of air, but all mixtures, from 1 of gas to 4 of air to 1 of gas to 14 of air are explosive.

The impossibility of the ignition of coal gas in the absence of air was illustrated on a large scale during the bombardment of Paris, when shells burst inside the gas-holders. In one case the gas was not even ignited; in others the issuing gas was ignited, and burned in a huge jet in the open air.

The coal gas generated in the furnace cannot be ignited below a red heat—perhaps 1,400 deg. F. An iron rod will not ignite the gas issuing from a burner at less than the colour due to about this temperature, and the heat should be maintained above this point within the furnace to ensure ignition of the hydro-carbon gases; or, in other words, the fire should never be smothered with too much coal at once. Benefit is often found by coaling only one side of the fire at a time alternately in moderately large furnaces.

It is evident, then, that more or less of the gases generated in the furnace may go away unconsumed, either owing to a deficiency in the supply of air or oxygen, or by reducing the temperature of the gases below the heat necessary for ignition, or if after ignition before the combustion or union is complete. The chill may be caused by the admission of too much cold air, or by too early abstraction by the boiler of heat from the flame. It is difficult to say which of these causes of loss most widely prevails, but probably in the majority of cases to the latter; for in many instances in which air is known to be in excess dense smoke is given off and even tarry matter deposited in the tubes, while a low evaporative efficiency is attained.

The "smoke" question may be here briefly dismissed with the remark that almost the whole of the smoke which issues from boiler furnaces is the product of flame prematurely extinguished, therefore any means of preserving the continuance of the flame until the completion of the combustion of the hydro-carbon gases must reduce the quantity of smoke produced.

The attainment of "perfect combustion" is rendered much more rapid and certain by the thorough mixture of the air and gas in proper proportions previous to ignition, as in the Bunsen burner; yet that the combustion of coal gas can be perfect when only the outer layers are in contact with the air is shown by the white and smokeless flame of every gas light. But more time and space are necessary in the case of the plain flame, owing to the smaller surface of the gas exposed for the combination with the oxygen. The value of the close proximity or incorporation of the oxygen with the fuel previous to ignition is illustrated by the greater rapidity and violence of the explosion—or combustion—of nitro-glycerine in comparison with gunpowder. Professor Cooke states that "in the gunpowder the carbon and oxygen atoms are in different molecules, although lying side by side in the same grains; in the nitro-glycerine they are in different parts of the *same molecule.*"

That the abstraction of heat from the flame of a candle prevents the completion of the combustion may be shown by holding around the flame—without actual contact—a ring half an inch inside diameter, formed on the end of a piece of copper wire say $\frac{1}{8}$ inch in diameter. This abstraction of heat causes the flame to smoke. Doubtless the same thing occurs in all ordinary tubular boilers consuming bituminous coal, as the temperature of the iron boiler tube will be but little above the temperature of the steam in the boiler—perhaps 350 degs.—while the heat of the flame will be at least 1,400 degs.

Sir H. Davy long ago discovered that "a mixture of air and gas would not take fire in a narrow metallic tube, because of the cooling influence exerted by the tube, and that the narrower the tube the shorter the length need be to exert this influence."

Davy further found that "a number of small apertures would not pass an explosion when their depth equalled their diameter." These experiments led up to his invention of the miners' safety lamp.

Professor Tyndall lucidly explains the reason of this extinction of flame, in his grand book, "Heat a Mode of Motion." He says, "A certain temperature is necessary to cause the gas to burn, and by placing wire gauze over the flame, or the flame over the wire gauze, the motion of that light and quivering thing is rapidly taken up by the comparatively heavy metal, which is a good conductor." The best way to avoid this premature extinction of the flame in the tubes of a boiler evidently is to *complete* the combustion of the gas *before* entering the tubes, or in other words to regard the generation of the flame as distinct from the heating of the boiler; the products of completed combustion to be afterwards conducted into the part of the boiler designed to abstract the heat from the gases.

That the fulfilment of these conditions would probably add greatly to the evaporative power of each pound of coal burnt in the majority of boilers, is indicated by the success recorded to have followed the adoption of the gas producer and suitable furnace to boiler purposes in several instances in Europe.

In ordinary practice, especially in marine boilers, the greatest drawback apparently is the want of sufficient space and temperature in the combustion chamber, in which to *complete* the combustion of the gases.

With regard to temperature: The writer has noticed that apparently less smoke was evolved from the boiler of a launch having an external combustion chamber, lined with fire tiles, than from the ordinary type of boiler in which the wet combustion chamber robbed the flame of heat. This evil of the too early abstraction of heat from the flame, is often greatly and unnecessarily increased by building the bridge wall too high, thus cooling the flame by causing it to impinge sharply on the boiler plate, which often suffers from the intense heat. Furnace bridges cannot well be too *low*.

The increased strength of corrugated boiler flues has, since their introduction, permitted furnaces to be made much larger in diameter, without exceeding the maximum thickness of metal admissible, and the additional space afforded between the fuel and the crown of the furnace for the mixing and the commencement of the combustion of the gases, is perhaps one of the best features of modern boilers.

The writer is of opinion, in as far *only* as improved combustion and prevention of smoke is concerned, that benefit would result in most marine boilers if the back, sides, and top of the combustion chamber were cased over with fire tiles; and, further, in the few cases where room could be spared in the combustion chamber, together with ample tube surface, a thin wall might possibly be hung in the combustion chamber, being placed about one-third of the depth of the chamber from the end of the tubes, and extending from near the top of the chamber down to about the level of the ordinary fire bridge. The ignited gases passing thus between red-hot brick walls would have more time and a higher temperature in which to complete combustion before being chilled, and the hanging wall would deflect the furnace gases towards the bottom of the combustion chamber, and the same time tend to thoroughly mix these gases. The practical objection

to the hanging wall, such as the choking of the lower tubes, and the want of durability of the brickwork must, however, prevent its use; but the object sought might be attained in a boiler specially designed. An American patented improvement of boiler furnaces which is now being advertised and pushed, appears to consist chiefly of the insertion of a fire arch *over* the fuel.

Perhaps one of the best examples of a nearly perfect solution of the difficult problem of rapid and *complete* combustion within a limited space is shown by the furnace of a powerful locomotive, in which as much as 150 lbs. weight of fuel per square foot of grate is burned per hour. For instance, as reported in *The Engineer* newspaper of March 20th, 1885: The "Gladstone" locomotive of the L.B.S.C. Railway has evaporated nearly 13 lbs. of water per pound of coal.

The furnace of a large locomotive usually measures about 5 feet in height from the fire bars to the crown of the furnaces. This large space above the fuel—large compared with ordinary marine or internally fixed land boilers—must contribute largely to the success of the furnace, a better opportunity being here offered for the completion of combustion.

The brick arch, placed about half way between the grate and the roof, and which usually extends out from the tube-sheet about five-eighths of the length of the furnace, must in its white hot condition have a highly beneficial effect in mixing and inflaming the gases and the air, and also by lengthening the run of the flame before entering the tubes. Yet without the "arch" the abundant space alone seems satisfactory, as instances are on record of actual loss of economy attending the adoption of the brick arch, although the weight of evidence is greatly in favour of the "arch."

The fire is usually worked so thick in the locomotive furnace that, notwithstanding the sharp draught, not nearly enough air to complete combustion can possibly be drawn *through* the fuel. The supplementary supply of air is then introduced above the fire, through a scoop deflector, and being directed by the deflector downwards on to the fuel, the air mixes with the gas coming from beneath the arch. The resulting flame fills the space above the

arch, and combustion is practically completed before the products enter the tubes, which are left to their only proper office of, as it were, sifting the heat out of the passing gases.

The combustion of the coke may either be completed at once by the full supply of air through the furnace bars, or, if the supply of air is restricted, the oxide produced may be burned together with the hydro-carbon gases as in Siemen's system. In practice this question is usually at once decided, as in the case of most boilers it is necessary to force the fires by frequent opening and slicing to pass a surplus of air through the fire, in order to burn sufficient weight of coal in a given time to keep up steam. But the question may remain open in the rare cases where there is sufficient *time* and *space* for the production and combustion of the increased quantity of gas. No doubt the production of the oxide is preferable, for a gas fire is much more under exact control than solid fuel or the ordinary fire of both the coke and gas, which is still more difficult to manage. Much valuable experience of gas fires on a large scale, applied to almost every purpose, must now be accumulating in the natural gas regions of the United States.

If the coke is at the first stage burned to carbonic di-oxide, this gas evolved must, from its well-known power of extinguishing flame, prove very inimical to the continuance of the desired flame in the combustion chamber. This effect is the more apparent when the large quantity of the carbonic acid is considered, as the 0·55 lb. of coke from each pound of coal forms about 2 lbs. of carbonic acid, or, say, about 50 cubic feet, at the furnace temperature.

One would suppose that by the production of the *oxide* from the coke that the hydro-carbon, or coal gas, flame would be in a measure preserved from the injurious presence of the carbonic acid; for the hydro-carbons in the presence of the C.O. having the stronger affinity would first seize on the oxygen if only a limited supply was present. By the addition of a further supply of air later on, the carbonic oxide (being already supplied with one-half of its quantity of oxygen in flames at a lower heat than the coal gas) might be burned *after* the coal gas, at a lower temperature and in a part of the boiler where the hydrogen flame could not exist.

Sir H. Davy states "that the addition of (only) one part of carbonic acid to a mixture of 7 parts of inflamable gas and air in the proper proportions, or of one part of hydrogen with 6 of the mixture, destroys their power of explosion—that is, ignition was prevented."

The combustion of the coke from 1 lb. of coal would produce about 2 lbs. of carbonic acid, and would be accompanied by about 6 lbs. of nitrogen; the ignition of 40 lbs. of the mixture of air and inflamable gas, containing about 2 lbs. of gas, as much as would be generated by, say, 5 lbs. of coal would thus be prevented. The absolute necessity for a large supply of air in excess of the quantity chemically required merely for the *dilution* of the carbonic acid gas is here evident in order to lessen its power of extinguishing flame.

It is probable that the check to combustion offered by the presence of carbonic acid or nitrogen is not due to any inimical property possessed by these gases, but may be solely due to their displacement of the oxygen preventing its access to the fuel. Although nitrogen is incombustible under ordinary circumstances and instantly extinguishes burning bodies, "under certain conditions, however, nitrogen does undergo combustion, as when it is exposed to a very intense heat in the presence of oxygen. This occurs, for instance, when a small quantity of nitrogen is added to a mixture of hydrogen with a somewhat larger proportion of oxygen than is required to form water, and the mixture is then ignited; a loud explosion takes place, and a considerable quantity of nitric acid is formed, owing to combustion of the nitrogen, or, in other words, its union with oxygen."

The great advantage of a thick fire—sufficiently thick to produce some carbonic oxide—is that the supply of air *through* the fire is more regular, and more easily adjusted than with a thin rapid fire, continually burning into holes, through which a large surplus of air is drawn; resulting in loss of heat up the funnel. Apart from the readiness with which a thin fire burns into holes, the difficulty of keeping a large grate surface *evenly* spread, with a thin fire is considerable, and, with most boilers—when a sufficiently

sharp draught is available—a reduction of the area of grate surface, and a consequent increase in the thickness of the fire and in the rate of combustion per square foot, is attended usually with increased efficiency and economy of fuel.

Mr. J. T. Milton has stated that "the sharper the draught the less surplus air for dilution of the carbonic acid is required." Therefore with a *sharp* draught less heat is lost by heating air chemically unnecessary.

With a strong natural or forced draught the jets of air entering the furnace at a high velocity must cause strong eddies, and a much more rapid and thorough mixture with the combustible gases ; just as a small strong jet of water directed into a bucket fully penetrates and mixes much more thoroughly than the addition of the same, or a larger, quantity in a slow dull stream. This is probably the chief reason for the increased economy attending forced combustion, to which general attention is now being drawn. So far, however, forced draught appears to have been adopted—as in the case of torpedo boats' boilers—chiefly with a view to secure increased boiler power, comparatively regardless of economy in fuel,—with the old exception in part of the locomotive.

Many years ago, in the early days of forced draught, it was found that with the fan of steam blast applied to a furnace, the air supply might be reduced 25 per cent.

That the slight pressure maintained in a furnace instead of the usual small vacuum caused by the chimney draught of equal power, cannot make much difference in so far as combustion is concerned—although it may make a great difference in the working of the boiler—as witness the case of the locomotive boilers of H.M.S. "Polyphemus," which, with the fires forced by fan blast, primed so insufferably that they had to be taken out of the ship—is proved from the following extract:—

Professor Tyndall found, in the *rarefied* air on the summit of Mont Blanc "that though the light-giving power of the flame of candles was diminished in an extraordinary degree, the rapidity of the combustion (and consequently of the heat given off) was

unchanged. This curious result is to be ascribed mainly to the mobility of the air at this great height. The particles of oxygen could penetrate the flame with comparative ease, thus destroying its light, and making atonement for the smallness of their number by the rapidity of their action.

I find, indeed, that by reducing the density of ordinary atmospheric air to one half, we nearly double the mobility of its atoms." With reference to the opposite step of *compressing* the air, Dr. Frankland showed twenty-five years ago "that the quantity of a candle consumed in a given time is, within wide limits, independent of the density of the air; and the reason is, that though by compressing the air we augment the number of active particles in contact with the flame, we, almost in the same degree, diminish their mobility and *retard* the combustion. One of the most interesting facts established by Dr. Frankland is, that by *condensing* air around it, the pale and smokeless flame of a spirit lamp may be rendered as bright as that of coal gas, and, by pushing the condensation sufficiently far, the flame may actually be rendered *smoky*, the oxygen present being too sluggish to effect the complete combustion of the carbon."

Causing the flame to be smoky is diametrically opposite to the effect desired in a boiler furnace. Yet Mr. C. W. Williams, the well-known able and practical writer on "The Combustion of Fuel," argues in favour of *condensing* the air, and strongly condemns the heating and consequent expansion of the air beforen entering the furnace; chiefly on the ground that "its already unwieldly volume is still further increased," and that "no natural draught would be equal to the volume of air were it doubled by heating to 512 deg."

After considering the deductions of Professor Tyndall and Dr. Frankland, the writer has the temerity to believe, such a high authority as Mr. Williams notwithstanding, that preliminary heating of the air for combustion, especially if it could be accomplished by heat which would otherwise be wasted, is highly desirable, for seeing that if it were practicable to heat the air before entering the furnace, to the temperature at which it after-

wards passes up the funnel, say 500 or 600 deg. F., an addition of nearly 50 per cent. would, with a corresponding addition to the heating surface, be made to the evaporative power of the fuel. Some part at least of this benefit might surely be secured.

The author has just finished a careful comparison, for economy of fuel, between two ordinary furnaces using cold air, and two similar furnaces, doing same duty, but supplied with air at 445 deg. F. (tin melts reluctantly in the current of air entering ash pit). Newcastle (N.S.W.) co-operative coal from the same cargo was used for each furnace, and the gases escaped in each case at about 900 deg. F.

The actual saving of coal in favour of the hot air supply has been each week 9·75 per cent., and 9.8 per cent., but these furnaces, although intended to do exactly the same work, also did 3 per cent. more work. Consequently the *real* saving in fuel is about 12·7 per cent. Theoretically the saving should, of course, be greater, but 10 per cent. is well worth having.

The activity of the atoms of oxygen while passing through the fire must be very greatly exalted, as the air at that temperature would be expanded, say, 4 times, and when leaving the boiler the air would still be expanded to double its volume.

It appears to the writer that Mr. Williams's objection to the "increased volume" caused by heating the air must be limited in application chiefly to the time during the mere *introduction* of the air into the furnace, for the cold air must be heated instantly on entry, at the expense of the "high temperature necessary in the furnace." The difficulties attending the "increased volume" of the heated air must therefore be the same both while *in* and *after leaving* the furnace, whether the air be admitted cold or hot.

A considerable number of instances on record might be quoted of benefit claimed to have attended the application of heated air to boiler furnaces.

As it is evident that the character of the operations which take place in the furnaces are chiefly governed by the quantity and manner of air supply, a crude but inexpensive and perhaps original method of estimating the air supply for ordinary furnaces working

with natural draught may now be noticed. Of course the quantity of air to be admitted into the furnace must be calculated entirely from the weight of fuel consumed, regardless of the area of grate surface. No empirical rules based on the velocity of draught due to a given height of and temperature in the funnel can prove satisfactory, owing to the widely varying degrees of obstruction to the draught between the furnace and funnel offered by different boilers.

The writer measures the actual draught—or, rather, partial vacuum—in a furnace by introducing a piece of iron gas-pipe, say ½ in. dia., and long enough to reach through a hole in the furnace front to about the centre of the furnace. On the outer end of the iron pipe a bend is formed, and a piece of glass tube attached—part of an old water-gauge glass. The open lower end of the glass tube being sealed in a little water, the height to which the water is raised within the tube then being measured, the rate at which the air will enter the furnace may easily be calculated from the following table. By multiplying the sum in square inches of the apertures supplying air to the furnace by the corresponding figures :—

Height of Water in Glass Tube.	Velocity of Air in Feet per Second.	Cubic Ft. of Air Passed p. Sq. Inch of Aperture p. Hr.	Lbs. Wt. of Air Passed p. Sq. Inch of Aperture p. Hr.
1/16th inch	12·8	320	23·7
1/8th ,,	18·4	460	34·
3/16th ,,	23·	575	42.6
1/4th ,,	26·4	660	48·9
5/16th ,,	29·6	740	54.8
3/8th ,,	32·24	806	59·7
7/16th ,,	35·	875	64·8
1/2 ,,	37·36	934	69·2

These figures have been calculated with a coefficient of 8/10th of the theoretical velocity and discharge; on the assumption that the air would be admitted into the furnace through perforated plates, the thickness of plate, and the diameter of the

hole, being about equal. The temperature of the stoke-hole is assumed to be about 75 deg. F., or 13·5 Cubic feet of air weighing one pound.

In this way, the quantity of air admitted *above* the fire may easily be estimated and adjusted, and with a little more trouble the supply of air passing through the fire may also be indirectly calculated. If the front of the ash pit is closed by an ordinary thin sheet iron damper plate, fitted with a sliding door, adjusted so that say a vacuum equal to a head of $\frac{3}{16}$ inch of water is formed under the furnace bars, and at the same time say $\frac{3}{8}$ inches of vacuum is found above the fuel in the furnace. The weight of air entering through the damper plate is then found by multiplying the number of square inches in the adjusted aperture by the corresponding figures in the table, viz., 42·6. It is evident that exactly the same quantity of air is at the same time passing through the fire. If the damper plate is then entirely removed, and the vacuum in the furnace again noted, and found to be, say, $\frac{5}{16}$ of an inch, then the same number of square inches being multiplied by the corresponding figures—54·8—must give the weight of air entering through the ash-pit.

The velocity at which the air enters the ash-pit could, no doubt, be most readily ascertained by one of Casella's Anemometers, but these instruments are expensive and probably difficult to procure in the colonies.

If a large supply of air is drawn through a very restricted ash-pit, a vacuum may be formed under the fire bars,—after the damper plate is removed—of say, perhaps, $\frac{1}{16}$ of an inch, which must be deducted from the vacuum observed in the furnace, before the calculation is made; but in ordinary cases this correction is not necessary.

Take the case of an ordinary furnace, say 3 feet in dia., by 6 feet long, and a thin open fire and good draught, burning say 450 lbs. of coal per hour; 20 lbs. of air being admitted per pound of coal. The air must thus pass under the dead plate, through about 3 square feet of cross section, at the rate of about 11 lineal feet per second, or equal to a vacuum of about $\frac{1}{32}$ of an inch of water.

The sum of the spaces between the fire bars usually amounts to about $\frac{1}{3}$ of the total grate area. A velocity of the air of about 6 feet per second,—or equal to a vacuum of $\frac{1}{100}$ of an inch of water—would thus suffice to admit the full supply of air. But a very great obstruction is offered to the passage of the air immediately after, just *at the top of the bars*; where the spaces are almost covered by the fire and debris, which apparently reduces the available area for the admission of air to from $\frac{1}{4}$ to $\frac{1}{7}$ of the sum of the apertures between the bars. Hence the increase in steaming power usually attending the use of thin fire-bars, giving as much air space as possible.

The total quantity of air to be admitted to a furnace, having been decided on, a brief consideration of the manner in which it may be introduced remains.

The whole of the air, from 18 to 24 lbs. weight, for the the combustion both of the coke and the volatile matter, and for the dilution of the carbonic acid, may evidently be admitted through the fire, if it is sufficiently open; or, the proportion of air passing through the fire may be restricted to about one-sixth part,—producing carbonic oxide, and the volatile gases—the remaining $\frac{5}{6}$ of the air being admitted above the fire for the combustion of these gases. Any intermediate proportion between these extremes in the supply of air through or over the fire may obviously be adopted.

In ordinary practice the supply of air passing through the fire is regulated almost entirely by the demand for steam, and by the state of the fire; which, if thin and clean, rapidly burns into holes which may admit a large surplus of air; or, on the other hand, the grate may be almost hermetically sealed, either by clinker and ash, by a thick fire which has been ground small by constant slicing, or by heavy charges of small caking coal.

Hence the necessity for an unceasing watch on the state of the fire, and the difficulty of regulating the supply of air entering above the fire in even proportion to the quantity entering *through* the fire. It is clearly desirable that the fire should be as much as possible maintained in a uniform

condition, which cannot be the case with heavy charges of fuel at long intervals.

Michael Reynolds in his book "Locomotive Engine Driving," truly says, that "The secret of first-rate firing is to fire *frequently, and a little at a time.*"

Whether much or little air be admitted either through or after the fire, the first object is to mix it thoroughly with the furnace gases, and it would appear that this object can best be attained by admitting the air *in small jets, at a high velocity across the current of the flame*, although, for the sake of convenience, the air is usually admitted either at the bridge, or more frequently through the furnace door or front.

The most economical thickness of an ordinary fire of the Newcastle Co-operative coal appears to be not less than 12 inches, or virtually as thick as it is possible to work the fire, so long as it remains clean.

The effect of admitting air through the furnace doors is marked. Recent experiments with one of a range of Cornish boilers (now under the care of the writer), shewed an increase of temperature (registered by a pyrometer in the outer flue of the boiler—indicating the temperature of the passing gases after a run of 60 feet from the furnace) with varying admission of air above the fire up to 80 square inches of aperture, or 4 square inches per square foot of grate. Each boiler is 7 feet dia., and 27 feet long, with 20 square feet of grate in a corrugated furnace and flue 3ft. 8in. dia.

About 400 lbs. of coal are burnt per hour with a vacuum in the furnace equal to $\frac{3}{8}$ths of an inch of water. (The chimney, 120 feet high, gives a draught of $\frac{3}{4}$ths of an inch.) With the 80 square inches of opening above the fire, about 12 lbs. of air will be admitted per pound of coal consumed, or enough chemically for the complete combustion of the coal, though at the same time at least as much air would be admitted through the fire.

The pyrometer is a very simple affair, merely a small stiff iron tube, 28 feet long, carried on bearers through the centre of the flue. One end of the tube is firmly fixed, and a long pointer rests

against a knife edge on the other end of the tube. The long arm of the pointer travels over a quadrant scaled 100 deg. F. to 3 inches. The scale was standardized up to 600 deg. F. by a thermometer. The temperature indicated will be the average obtaining throughout the flue. This little arrangement is extremely sensitive, the slightest alteration in the admission of air, or in the state of the fire being almost instantly responded to. The increase of temperature shewn in the outer flue, when 80 square inches of aperture is suddenly opened above the fire, averages about 60 deg. F., with a fire either of coal or coke. When the apertures above the fire are suddenly closed again, the pointer usually drops as rapidly as it had risen previously. The temperature indicated with ordinary firing ranges from 750 deg. to 800 deg. F., usually standing at or near 760 deg. F. The highest temperature noted with a clean fire of round coal and hard firing was 850 deg. F.; but with a clean coke fire 1050 deg. F. has been registered, indicating probably a long flame of C.O., and shewing that the temperature in the outer flue is *not* in proportion to the rate of evaporation, nor to the value of the fuel as the coke possessed only about $\frac{4}{5}$ths of the evaporative power of the coal. The 12lbs. weight of air admitted in excess above the fuel, and finally leaving the boiler at about 500 deg. F. must carry off sufficient heat to evaporate about $1\frac{1}{2}$lbs. of water, or 20 per cent. of the duty of the boiler. Yet the weight of water evaporated per pound of coal only falls off about 3 per cent., thus shewing that more perfect combustion must have been attained, although the resulting increase of heat generated cannot all be abstracted from the larger volume of less highly-heated gases travelling more rapidly past the heating surface of the boiler. This effect of the admission of an excess of air to the furnace in distributing the heat more evenly over the heating surface of a boiler is sometimes utilized with advantage in the case of boilers that prime badly, by setting the furnace door ajar. Some sacrifice of economy of fuel may follow owing to the difficulty of abstracting the heat from large volumes of gases at comparatively low temperatures, as the rate of conduction is in proportion to the difference in

temperatures between the source and the recipient of heat. With ordinary strength of draught, a square foot of heating surface near the smoke-box end of a boiler tube evaporates only about $\frac{1}{16}$ as much water as a square foot of the fire-box, although the differences between the temperatures in the furnace, and in the tube respectively, and the temperature of the boiler are only about 3 to 1. The increase of air pressure in the furnace accompanying most systems of forced draught must tend to localize the heat, and to increase the evaporation effected by the furnace. While increased chimney draught, and consequent vacuum in the furnace, must tend to distribute the heat, and equalise the percentages of the total work done by the furnace tubes—or other heating surfaces respectively. A high furnace temperature being undoubtedly necessary in order to secure complete combustion, it would therefore appear that any successful attempt to raise the temperature in most ordinary furnaces would prove beneficial, especially when it is borne in mind that in the case of internally fired tubular boilers—as estimated by Peclet, and corroborated by recent American experiments—*half* of the available heat is at once abstracted, as radiant heat, by the plates of the furnace. There is usually besides this the drain on the furnace temperature of heating, say, at least, 10 lbs. weight of air per pound of coal, above the quantity chemically necessary, to say 1500 deg. F.; which would be equal to the evaporation of over 3 lbs. of water. It is true that $\frac{2}{3}$ of this heat is afterwards returned to the boiler through the tubes; but the restitution of heat is too late to assist combustion.

Several authors agree that in well-arranged furnaces, with the natural draught, half the oxygen admitted passes away uncombined.

The loss caused by the admission of any considerable surplus of air to the furnace being so large, it is desirable to ascertain in what state of the fire the smallest proportion of oxygen is passed through unburned.

The repeated and careful analysis of the burnt gases from the boiler flue before referred to, in which the pyrometer was placed,

revealed the somewhat unexpected result that *the amount of oxygen passing unchanged through the fire, in every case increased almost uniformily in proportion as the fire became dirty and choked.* After the fire had been recently cleaned, and with a thick hot fire of clean coke and a sharp draught, no air being admitted above the fire, the pyrometer indicating 1030 deg. F.; 20 per cent. of oxygen admitted was found to have passed through the fire unchanged. After the fire had run for four hours the percentage of uncombined oxygen rose to 30 per cent., and after six hours to 55 per cent. At the end of six hours a thick continuous and apparently almost impervious clinker had covered the bars, the production of steam being reduced to about one-fourth.

It is thus clearly desirable to maintain the fire *constantly* in a clean open condition, and to work with as much draught as possible, the thickness of the fire being regulated by the strength of draught available.

The following are average examples of the actual partial analysis:—

FIRE OF COKE, 14 INCHES THICK.

	1 hour after Cleaning.	$3\frac{1}{2}$ hours after.	6 hours after Cleaning.
Carbonic acid, including SO_2	16 per cent.	14.2 per cent.	9.3 per cent.
Carbonic oxide...	none.	traces.	0.4 per cent.
Oxygen ...	4 per cent. = 20 per cent. of total.	6 per cent. = 30 per cent.	10.9 per cent. = 54.5 per cent.
	20.	20.2	20.6
Tem. in flue ...	1030 deg. F.	800 deg. F.	650 deg. F.

FIRE 10 INCHES THICK, OF NEWCASTLE CO-OPERATIVE SMALL COAL.

	1 hour after Cleaning.	4 hours after.	8 hours after, fire very dirty.
Carbonic acid } including SO_2 }	13.2	13.4	11.3
Oxygen ...	3.2 = 16 per cent. of total.	6.6 = 33 per cent.	8.0 = 40 per cent.
Carbonic oxide and moisture not estimated.			
	16.4	20.0	19.3
Tem. in flue ...	830 deg. F.	790 deg. F.	630 deg. F.

Fire 12 inches thick, of Newcastle co-operative round coal, 2 to 3 hours after cleaning, or average condition—

Carbonic acid, including SO_2	12.2
Oxygen	7.5 = 37.5 of total.
	19.7

On the following pages will be found an extract from a summary of some practical tests of the comparative evaporative powers of several kinds of fuel. The figures given are the averages of many closely-corresponding tests of each kind of fuel. The tests averaged about eight hours duration each. The fire was drawn about seven each morning, and a fresh fire started from weighed coal; the time, the register of feed meter, and level of water in the boiler being noted. At the conclusion of each trial the fire was allowed to burn entirely out, the water in the boiler then being pumped up—a trifle only—exactly to the mark. The nearly constant temperature of the feed water, after passing through a Green's economiser, averaged 168 deg. F. The accuracy of the water meter was frequently tested. The ash and clinker were weighed together; the soot and flue deposit *not* being included.

Extract from Summary of some Meter Tests of Evaporative Powers of Fuels at Auckland Sugar Refinery, July, 1885, to March, 1886.—EDWIN C. STABLES.

Description of Fuel.	Lbs. Feed Water @ 168 deg. F actually evaporated per lb of fuel (add ·045lbs to each quantity if from 212 deg. F.)	Gallons of Water @ 168 deg. evaporated per ton of Fuel.	Weight of Fuel to evaporate 100 gallons from 168 deg. F.	Normal rate of Evaporation in gallons per hour by one boiler.	Lbs. Feed Water evaporated per sq. ft. of (600 sq. in.) heating surface in lbs per hour.	Coal burnt per sq. foot of (20 sq. in.) grate-bar surface in lbs. per hour.	Percentage of Ash and Clinker. (Dry.)	Price per ton of Fuel in Stoke-hole.	Gallons of Water @ 168 deg. F. evaporated for £1	Value per ton of Fuel, compared with Co-operative *Round*, @ 23/3. A	Value per ton of Fuel, compared with Co-operative *Small* @ 16/-. B	Value per ton of Fuel, compared with Westport *Small*, @ 18/3. C
Co-operative *Round* Coal ... Newcastle, N.S.W. A	7·0	1568·	143·lbs.	297· Max. 377 with forced firing.	4·95	21·17	11·3	23/3	1348·	23/3	17/3	16/5¼
Co-operative *Small* ... ... B	6·6	1478·4	151·	249·	4·38	18·85	11 75	16/3	1819·	21/11	16/3	15/5¾
Ferndale *Round*... ... ... Newcastle, N.S.W.	7·2	1612·8	138'8	288·	4·8	20·0	9·3	22/3	1450·	23/11	17/8¾	16/10½
Ferndale *Small*	6·5	1456·	154·	243·4	4·05	18·65	9·23	16/3	1792.	21/7	16/-	15/3
Newcastle Coal Co.'s *Round* ...	7·2	1612·8	138·8	364·	6·07	25·3	9·	22/3	1450·	23/11	17/8¾	16/10½

Newcastle Coal Co.'s *Small* ...	6·6	1478·4	151·	243·	4·05	18·46	9·6	16/3	1819·	21/11	16/3	15/5¾
Bay of Islands, N.Z. *Round* ...	6·27	1411·2	159·4	335· Max. 411½	5·583	26·7	10·3	20/3	1392·	20/10	15/5	14/8½
Kamo—Top Seam ... ... Whangarei, N.Z.	5·6	1254·4	178.	252·	4·2	22·445	6·23	13/9	1824·	18/7¼	13/9½	13/1¾
Kamo—Lower Seam	5·25	1176·	190·	261·1	4·35	24·868	5·48	13/9	1710·	17/5¼	12/11¼	12/4
Whau-Whau *Round* ... ... Whangarei, N.Z.	4·86	1088·6	205·7	252·5	4·2	26·0	9·8	13/9	1583·	16/1¾	11/11½	11/5
Taupiri Unscreened ... ... (damaged by weather) Waikato, N.Z.	4·65	1041·6	215·	268·	4·46	28·8	3·32	16/3	1282·	15/5¼	11/5¼	10/11
Greymouth, N.Z., Coal ... (damaged by weather)	7·4	1657·6	135·	272·5	4·54	18·4	7·0	36/3	914·5	24/7	18/2¾	17/6
Round Coal, Westport, N.Z. ... C	8·544	1913·85	117·	355·	5·916	20·75	2·0	23/3	1646·	28/3	21/0½	20/0½
Small Coal, Westport, N.Z. ... C	7·777	1742·	128·7	281·	4·6816	18·05	2·0	18/3	1909·	25/10	19/-	18/3
" Duckinfield *Small* " ... Newcastle, N.S.W.	6·6	1478·4	151·	275·5	4·59	20·875	11·9	16/3	1819·	21/11	16/3	15/5¾
J. & A. Brown's *Round* ... Newcastle, N.S.W.	7·17	1606·	139·4	319·	5·316	22·9	10·2	22/3	1443·6	23/9¾	17/7¾	16/10
Auckland Gas Co.'s *Screened Coke*, chiefly from Greymouth, N.Z., Coal ...	6·3	1411·2	158·7	323·2	5·386	25·75	8·8	15/3	1851·	20/11	15/6	14/9¼
Auckland Gas Co.'s *Small Coke* (average sample) ...	4·637	1038·68	215·65	213·8	3,563	23·05	8·5	10·3	2026·	15/5	11/5	10/10½
Best Rough Coke from own Retorts, from Co-op. N.S.W. Coal	6·95	1556·8	...	302·			13·1					

19TH JANUARY, 1887.

W. D. CRUICKSHANK, PRESIDENT, in the chair.

THE following candidates were balloted for and duly elected as

MEMBER:

E. C. WOOD.

ASSOCIATE:

J. V. DALGARNO.

STUDENT:

F. W. CAPE.

Mr. T. Stewart then read a paper on "Electric Lighting," an abstract of which will be found at the end of volume.

10th February, 1887.

W. D. Cruickshank, President, in the Chair.

The following candidate was balloted for and duly elected as

MEMBER:
H. G. M'KINNEY.

Professor Warren then read the following paper:—

THE ADHESION OF CEMENT AND OF VARIOUS CEMENT MORTARS TO BRICKS,

And its application in the design of Retaining Walls, Arches, and similar structures.

By Professor Warren.

In a paper entitled "Notes on Cement," which was recently read before this Association by Mr. A. C. Mountain, M.I.C.E., the various tests recommended by authorities on Portland Cement were fully considered and criticised. The tests described in Mr. Mountain's paper for ascertaining the value of a given cement, either for mixing with sand to form concrete, or with various aggregates to form mortar, are very satisfactory, and leave little else to be desired in so far as the cement itself is concerned. But while admitting the value of these tests, it must be conceded that it is at least as necessary to know the properties of the materials generally associated with cement in mortar and concrete, which, in conjunction with the cementing material, exercise an important influence in resisting the forces which are developed in the concrete or mortar in the uses to which they are applied by the engineer and architect.

Consider, for example, the behaviour of a mass of concrete formed of blue metal, sand, and cement, when subjected to a crushing force in the testing machine. Here the concrete will fail, not by the actual crushing of the material forming the aggregate,

but by a separation of the pieces of blue metal from the cementing material which binds them together. So that while the mass, as a whole, is subjected to an externally applied crushing force, the interior is called upon to resist forces which develop to some extent the tensile strength of the cement, but which fully develop the adhesive strength of the cement mortar, and the materials forming the aggregate. If the resistance of the cementing material to be thus separated from the material with which it is united is less than its tenacity, it follows as a consequence that the adhesive strength of cement is at least as important as its resistance to simple tension. The adhesion of cement, and of various cement-mortars to bricks forms the subject of this paper.

The only experiments known to the author on this subject are to be found in a work entitled "Strength of Cement," by Mr. John Grant, M.I.C.E. These were conducted as follows:—blocks of four bricks were cemented together with Portland cement and lime mortars of various degrees of richness; after twelve months the blocks were subjected to a tensile stress in a testing machine until they yielded at one of the joints, the force required to thus separate the bricks divided by the area of join gives the adhesive strength of the mortar. Mr. Grant's table of experiments is here reproduced (see Table I.). Several of the results recorded in this table appear inconsistent, and they have been put in bolder figures in order that they may be more easily noted. Mr. Grant says, that he considers many more experiments should be made before any trustworthy deductions could be made from them, and that there are considerable mechanical difficulties in making this class of experiments with any machine which combines the necessary strength and delicacy.

The experiments made by the author with the aid of the University Testing Machine were as follows:—

FIG. 1.

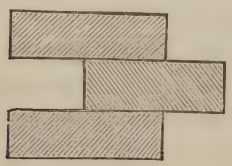


FIG. 2.

The bricks were set in two ways, which are shown in figs. 1 and 2. They were set in the cement room at the Town Hall, Sydney. The material used in forming the mortar, and the method of determining the exact proportions, and the mixing of the materials will be again referred to. The bricks, after being set in the manner described, were allowed to remain in the cement room for periods of 7 and 28 days respectively, after which they were carted to the University and tested. Every care was taken to ensure that the specimens were not damaged in carting, loading, and unloading, and only two specimens out of one hundred and fifty-six were damaged. The testing consisted in causing the middle brick in fig. 1 to slide between the two outside ones, thus overcoming the adhesion existing between the mortar and bricks on two surfaces. In fig. 2 one brick was made to slide upon the other, which developed the adhesion on one surface only. As might have been anticipated, it was found to be impossible to cause the force to be equally distributed over the two surfaces in Fig. 1, and in nearly every case one side failed before the other, so that the results obtained by testing as in Fig. 2 do not differ much from those obtained by testing as in Fig. 1. In future experiments on this subject the author proposes to arrange the specimens as in Fig. 2 only.

Materials.—The bricks used were made by Messrs. Goodsell Bros., St. Peter's, three months before they were used in adhesive tests. They were thoroughly soaked in water before using, and the average absorption was found to be 7.6 per cent. They were subjected to a crushing test both on the bed and on end, and gave the following results: —

No.	Description.	Size.	Weight.	Area exposed to Crushing.	Total force required to crush brick.	Force per sq. inch.	Remarks.
			lbs.		lbs.	lbs.	
1	Pressed brick as used in adhesive tests.	8·7 x 4·2 x 2·3	8¼	36·54	98,000	2682	Tested on bed cracked at 40,000 lbs.
2	Do.	8·7 x 4·2 x 2·3	7½	9·66	27,000	2795	Tested on end.

The Cement used was the "Castle Brand," No. 67, manufactured by W. Levett & Co. The materials which were mixed with the Cement to form mortar consisted of Crushed Sandstone, Nepean River Sand, and Blue Stone dust. They were each passed through a sieve, having 400 meshes per square inch, and the residue rejected. The degree of fineness of the material which had passed through a sieve with 400 meshes per square inch was tested by passing it through a sieve having 900 meshes per square inch, and the percentage of fine stuff which was thus passed through was as follows :—

Sand derived from Crushed Sandstone	67·1	per cent.
Sand derived from the Nepean River.....	39·0	,,
Blue Stone Dust	71·8	,,

The materials which were fine enough to pass through the sieve of 400 meshes per square inch were each mixed with the Cement by hand, on a slate table, in the following proportions by bulk, 1 to 1, 2 to 1, 3 to 1 and 4 to 1.

Mixing.—In order to mix the materials in the required proportion, the following method was adopted :—

The weight per imperial bushel of the cement was first ascertained, and the weight of a cubic inch derived from it by dividing this weight by the number of cubic inches in an imperial bushel.

The weight of the materials used with the cement to form mortar was ascertained by filling a measure $\frac{1}{10}$ the volume of the imperial bushel with the material in question, and well shaking it down. The measure and its contents were then weighed. The same measure was again filled with a copper funnel and again weighed, the mean of the two weights thus obtained was taken, and the weight of the measure deducted, the result was then divided by the number of cubic inches in the measure, the weights thus formed were as follows :—

Neat Cement—No. 67, Castle Brand...	0·7411	oz. per cubic inch.
Sand obtained from Crushed Sandstone	0·7787	,, ,,
Nepean River Sand	0·8509	,, ,,
Blue Stone Dust	0·9771	,, ,,

In order to mix the materials in the required proportions by bulk, it is only necessary to weigh out the material in accordance with these results. Thus, for example, to find out the quantities necessary for mixing Nepean river sand and cement in the proportion of 3 to 1, weigh out 0·7411 ounces or pounds of cement, and 3 × 0·8509 ounces or pounds, as the case may be, of Nepean river sand.

The percentage of water used in mixing the materials was found to be as follows :—

Neat Cement	... ...	... ...	23·4 per cent.
Crushed Sandstone	1 to 1	... ...	21·1 ,,
	2 ,, 1	... ...	17·7 ,,
	3 ,, 1	... ...	19·2 ,,
	4 ,, 1	... ...	18·4 ,,
Nepean River Sand	1 ,, 1	... ...	18·2 ,,
	2 ,, 1	... ...	12·5 ,,
	3 ,, 1	... ...	11·6 ,,
	4 ,, 1	... ...	11·17 ,,
Blue Stone Dust	1 ,, 1	... ...	19·7 ,,
	2 ,, 1	... ...	16·8 ,,
	3 ,, 1	... ...	16·1 ,,
	4 ,, 1	... ...	16·5 ,,

The results of the experiments are recorded in Tables II., III., IV., V., and these are summarised in Table VI. Table VII. was prepared by Mr. Mountain, from experiments made with the same brand of cement as that used in the adhesive tests. The tensile strength of this cement was found to be—

At the end of 3 days,	... ...	472 lbs. per square inch.
,, ,, 7 ,,	... ...	609 ,, ,,
,, ,, 28 ,,	... ...	740 ,, ,,

By comparing these results with those given in Table VII., the relative adhesive strength of this cement to the materials enumerated in the Table may be inferred thus. When mixed with crushed sandstone in the proportion of 1 to 3, the tensile strength was found to be 191 lbs. per square inch at the end of 7 days, and 219 lbs. per square inch at the end of 28 days. Now, although a tensile force has been applied in this case, the internal resistances developed in the briquette were the adhesive strengths of the particles of cement to the particles of sand, and thus, from the experi-

ment quoted, is 0·311 times that of the tensile strength of the neat cement at the end of 7 days, and 0·296 times at the end of 28 days, giving a mean value of 0·3035, which may be used as a co-efficient to calculate the adhesive strength of crushed sandstone to the cement when mixed in this proportion. In a similar manner other co-efficients may be derived which may be used in like manner. The adhesive strength of neat cement mortar to the bricks experimented upon may be found by multiplying the tensile strength of the neat cement by 0·275.

Applications.—The foregoing facts have an important application in the design and construction of enclosure walls, retaining walls, piers, abutments, buttresses and arches. With regard to retaining walls the following conditions are usually accepted :—

a. When the wall is subjected to fluid pressure on one side only :

1. The centre of pressure when the water reaches its highest position must fall within the centre third of the thickness of the wall at every level.
2. The centre of pressure due to the weight of the wall itself must fall within the centre third of the thickness of the wall at every level. (Note.—This will happen in every case unless the wall or dam is exceptionally high.)
3. The intensity of the vertical pressure at the outer face must not exceed that which the material can safely bear.
4. The angle which the resultant pressure on any bed joint makes with the normal to that joint must not be greater than the angle of which $\frac{4}{5}$ of the co-efficient of friction of material is the tangent.

b. When the wall is subjected to earth pressure on one side only :

Here the same conditions apply, with the exception that in condition 1 we substitute the maximum earth for the maximum fluid pressure due to water. In all ordinary retaining walls which satisfy this condi-

tion, the intensity of vertical pressure on the outer edge will not generally exceed the safe limit with regard to crushing of material.

c. In dock and quay walls, which are subjected to both water and earth pressure, the walls must be designed to resist the maximum earth thrust when the dock is empty, and the maximum water pressure, less the minimum earth thrust, when the dock is full.

With regard to arches: The line of resistance is supposed not to pass without the centre third of the thickness of any voussoir, and its direction at any joint must not make with the normal to the joint an angle greater than the angle of friction of the materials. Similar conditions are accepted with regard to piers and abutments of bridges, &c.

In all such cases as the foregoing it has been the usual practice to work in accordance with the above conditions, for if the line of pressure in a retaining wall, or the line of resistance in an arch, passes outside the middle third of the thickness of the arch or wall, as the case may be, it is generally assumed that there will be an insufficient margin of stability, and that the intensity of pressure on the edge nearest the line of pressure may exceed the safe limit, and that the edge furthest from the line of pressure will be entirely relieved of pressure. These will undoubtedly be true if the joint in question is incapable of resisting tensile stress. If, however, the adhesive strength of the mortar in the joint is relied upon to resist the tensile stress, which will be developed at the joint by the deviation of the line of pressure from the middle third of the thickness, the distribution of pressure will be considerably modified, and a much thinner wall be found sufficient.

The following examples have been chosen to illustrate a method of dealing with such questions, and to show how much the adhesive strength of the mortar may increase the strength of such structures.

EXAMPLE.—To determine the thickness of a retaining wall at the base, having given the thickness at the top and head of water, first, when there is no tension on the joint AB, and, secondly, when tension is developed at the corner A.

First, when there is no tension at A,

Let the thickness of the wall at top be ... ... 4′ 0′

,, ,, head of water ... ... 20′ 0″

,, ,, material of the wall be concrete weighing 140lb per cubic foot

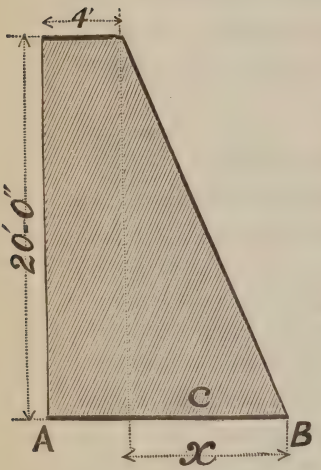
,, x be the extra thickness of the wall at the base

Then the area of the wall will equal ... ... $10\,(x+8)$

,, ,, weight ,, ,, ,, ... $1400\,(x+8)$

Let the distance of the centre of gravity of the wall from the edge B = X.

Then $10\,X\,(x+8) = 10x \times \frac{2x}{3} + 80\,(x+2)$



$$X = \frac{\frac{20x^2}{3} + 80\,(x+2)}{10\,(x+8)}$$

The distance of the centre of gravity of the wall from C where BC = $\frac{1}{3}$ AB is

$$= \frac{\frac{20x^2}{3} + 80\,(x+2)}{10\,(x+8)} - \frac{x+4}{3} = \frac{10x^2 + 120x + 160}{30\,(x+8)}$$

Take moments about C, then moment of wall

$$140\,(x+8)\left\{\frac{10x^2 + 120 + 160}{30\,(x+8)}\right\}$$

$$= 1400\,(x^2 + 12x + 16)$$

Moment of water = $\frac{1}{6}wh^3 = \frac{62{\cdot}5 \times 8000}{6}$

$$\therefore \frac{62{\cdot}5 \times 8000}{6} = 1400\,(x^2 + 12x + 16)$$

$x = \pm 14{\cdot}5 - 6$, taking the upper sign we find $x = 8{\cdot}5$. Hence the total thickness of the wall will be 12·5 feet at base.

Secondly, when there is tension at A.

Take the moments in this case about B instead of C. Then

$$1400(x+8)\left\{\frac{\frac{20x^2}{3} + 80\,(x+2)}{10\,(x+8)}\right\} = \frac{140}{3}\left\{20x^2 + 240\,(x+2)\right\} = \frac{62{\cdot}5 \times 8000}{6}$$

$$x^2 + 12x + 24 = \frac{62{\cdot}5 \times 8000 \times 3}{6 \times 2800} = 90$$

$x = -6 \pm 10$ = neglecting negative sign, 4 feet.

Hence the thickness of the wall will be 8′ instead of 12′ 6″.

We will now investigate the distribution of pressure and tension on the point AB.

Area of wall = 20 × 6 = 120 square feet.
Weight of wall = 140 × 120 = 16,800 lb.

The distance of centre of gravity of the wall from A

$$= X = \frac{\frac{40 \times 8 + 80 \times 6}{3}}{120} = \frac{8}{9} + 4 = 5 \text{ nearly.}$$

Let N = normal pressure per lineal foot of length of wall = 16,800 lb.
Let Y = distance of centre of gravity from B = 3 − 5 = 3 ft.
t = thickness of wall = 8 ft.
Let n = the intensity of pressure at A.
„ n' = „ „ „ B.
Then it can be proved that

$$n = \frac{2t-3y}{t} \times \frac{2n}{t} = \frac{16-9}{8} \times \frac{33,600}{8} 3675 \text{ lb per sq. ft.}$$

$$n' = \frac{3y-t}{t} \times \frac{2n}{t} = \frac{9-8}{8} \times \frac{33,600}{8} = 525 \text{ lb per sq. ft.}$$

Moment of flexure about the section AB = $\frac{1}{6}wh^3$
„ „ resistance „ „ „ = $\frac{1}{6}bd^2f$

$$\therefore \quad wh^3 = bd^2f \qquad \because \quad f = \frac{wh^3}{bd^2} = \frac{62{\cdot}5 \times 8000}{8 \times 8} = 7182{\cdot}5$$

Therefore the compression at B = 7812·5 + 525 = 8337·5 lb per ft.
„ „ tension „ A = 7812·5 − 3675 = 4137·5 „ „

Compression at B = 57·8 lb per sq. in.
Tension at A = 28·7 „ „

On referring to Table VI. it will be seen that this tension is not excessive with any of the mortars which consist of cement and sand in the proportion of one to one, and the crushing resistance of good concrete may be taken as 1000lbs. per square inch (see remarks given in discussion of Mr. Mountain's paper).

This system of construction is especially applicable to structures having a rock foundation, but it may be applied in many other cases if the footings be sufficiently spread out to prevent the pressure of the wall on the foundations exceeding the safe limit. The advantages in uniting the base of a wall built under water to a rock foundation with good cement mortar are obvious, as the water will be prevented from finding its way under the wall and exerting an upward pressure equal to the weight of the water displaced by the wall. Moreover since the adhesion of the cement to the rock will allow tensile stresses to be developed at the joint, it follows that the thickness of the wall usually adopted in such cases might be reduced without any risk of danger.

The author desires to thank Mr. A. C. Mountain, M.I.C.E., for co-operating with him in making the experiments described in the paper, and to Mr. Errey for his care and intelligent assistance, both in the preparation and testing of the specimens.

DISCUSSION.

Mr. Trevor Jones desired to signify his appreciation of Professor Warren's pains-taking experiments to deal with the very important question of retaining walls from some new points of view, as in the case under consideration involving the adhesiveness of mortar.

The question of retaining walls was one that, if approached in an incautious manner, was likely to lead its students into pitfalls; the consideration of the question embraced many features not to be hastily dealt with.

Cement mortar had been tested for its tensile resistance with great care and pains, but while that quality, if satisfactory, had proved a fair indication of its power to sustain pressure, nevertheless, direct experiments on its crushing, cross breaking and even shearing resistance had the most important value, in view of the many uses that cement was being put to in modern structures.

With reference to retaining walls generally, the adhesive property of cement had been all but ignored, and indeed he would not now advocate entire dependence to be placed on that quality. He was still of opinion that the inner toe of a retaining wall should not be subjected to tension.

Meantime the author had shown that a retaining wall may safely be designed showing a substantial reduction in substance by the use of cement in place of lime mortar.

One source of insecurity in building with lime mortar, especially if the wall was to sustain pressure within a short period of its being built, arose from the fact that lime mortar took months, to set, and therefore, instead of constituting an element of stability, it afforded a pasty lubricant (if rich in lime) for the stones to slide one on another.

Lime within the heart of a thick wall could not collect sufficient carbonic acid gas from the air for setting purposes, it was well known that if lime paste was kept in a box covered with water, it would not set in 100 years, because it could not collect its carbon to set with if not in contact with air.

In connection with the question of utilizing the cohesive property of cement for retaining walls, some time since he made some experiments in that direction and had conferred with Professor Warren on the subject.

The Professor had shown, that a wall to sustain a head of water of 20 feet must at least be 8 feet in thickness; it might at first glance surprise one that he had built a brick wall, to sustain the same head, only $4\frac{1}{2}$ inches in thickness, and it had sustained that load without any failure; moreover by calculation it could be raised to 30 feet.

The tank in question was an upright cylinder of $4\frac{1}{2}$ inches brick, 10 feet in diameter internally, built upon and accurately cemented to a rock foundation. This was rendered inside with $\frac{1}{2}$ inch of 1 to 1 cement mortar.

As the maximum bursting stress was on the bottom brick, the water pressure, computed as for pipe or boiler pressure, exerted a pressure at 20 feet depth, of $20 \times .434 = 8.7$ lbs per square inch and from $T = Pr$ or the tension in the enclosing wall = the pressure per square inch multiplied by the radius, all in inches, we had $T = 8.7 \times 60 = 522$ lbs.

Well, the lower brick had to sustain a tension of 522 lbs., or to part from its fellows under that tension; here the tensile strength of the cement would be shown to be more than sufficient to obviate the latter event; moreover the lower brick gained a large access of strength from the superincumbent weight of the wall above.

A brick wall of $4\frac{1}{2}$ inches in thickness in cement would bear in tension a pull of $4\frac{1}{2} \times 290$ lbs. = 1305 lbs., hence without counting on the adventitious strength derived from the weight of wall and $\frac{1}{3}$ an inch of cement, the wall was $2\frac{1}{2}$ times the actual thickness necessary to burst the tank.

This tank had been built to be burst, if 20 feet should be found sufficient to do so, but having withstood the test it still remained to be shown what head would burst it; not that he would for a moment advocate the utilising of such tanks for any purpose, excepting that it demonstrated that the cohesive property had a certain appreciable value.

If we took for example a tank of 50 feet diameter, the strain on the bottom inch layer would be 5220 lbs., to sustain which, assuming brickwork to afford a resistance of 290 lbs. per square inch, a thickness of 18 inches would just sustain it, while a thickness of 4 feet 6 inches would give a factor of safety of 3.

Now if such a wall were to resist overturning as computed from standard methods, it had been shown that its minimum thickness should be 8 feet; was it not plain that if a 4 feet 6 inch wall was three times the strength to resist the strain, or if even this factor be thought too small there must be a thickness between the two extremes that would afford ample security with economy.

He had extended his remarks too much to enter on the consideration of the saving that might further be effected by a taper section, and concluded by saying that the profession could not have too much information on the subject treated of so ably by our valued colleague, Professor Warren.

Mr. SHELLSHEAR remarked that he thought the paper a most valuable addition to the proceedings of the Association. Up to the present there was a great want of proper experimental data to guide the engineer in the use of local materials, and the recent tests at the University by Professor Warren would do much to supply that want. With reference to the construction of retaining walls, no doubt where there was a really good foundation, considerable economy could be effected in the direction pointed out, but it often occurred that walls had to be built on anything but first-class foundations, in which case it would not be prudent to reduce the section of the wall. The very interesting experiment referred to by Mr. Trevor Jones showed how much could be done

in the way of reducing the section of walls when the foundation was really good, but if a similar experiment had been tried on inferior ground the result would have been very different.

Professor Warren, in reply, stated that it appeared to be generally admitted that cement mortar was superior to lime mortar for such structures as retaining walls, arches, abutments, &c., not only on account of the increased strength of the structure in consequence of the greater adhesive strength of the cement mortar, but from the fact that it would set equally well in the interior of a brick wall, under water, or when simply exposed to air. Lime mortar set by the absorption of carbon dioxide which formed small crystals of carbonate of calcium in the joints. It could only crystalise where it was exposed to the atmosphere, from whence it derived its carbon dioxide, and hence could never set in the interior of a thick wall. He saw a retaining wall the other day which had partly fallen, and he obtained from the interior a quantity of lime mortar which was quite soft.

Mr. Jones had stated "that he did not think the inner toe of a retaining wall should be subjected to tension." This was equivalent to ignoring the adhesive strength of cement mortar, but the interesting experiment described by him appeared to the author to be another example of adhesion, not of tension as stated by the author. The method of calculating tensile stress on a ring of brickwork from the formula $T = Pr$ was strictly true for a thin film subjected to internal pressure; it was generally accepted as true for a boiler shell, and he did not think there was any considerable error in applying it to such a case as the one under consideration. Although the weight of the hollow column of brickwork was neglected, as well as the strength of the inside rendering of cement, the former in a tank of 10 feet in diameter, and $4\frac{1}{2}$ inches thick, might be neglected, but when this same system was applied to a tank 50 feet in diameter, or 500 feet in diameter, it failed entirely, and the results obtained were absurd.

The exact treatment of circular reservoirs was much more complex, and would form a good subject for a separate paper.

Taking Mr. Jones' calculations as correct for the 10 feet tank, we obtained the circumferential tensile stress as 523 pounds per square inch for the lowermost inch, and assuming this to remain constant for the lowermost 12 inches, we had $522 \times 12 = 6264$ pounds, which must be resisted by the four lowermost courses of brickwork. These may fail in two ways (1) either by separating along the line of vertical and horizontal joints, which would develop the adhesive resistance of the cement mortar (2) or by rupture of the bricks by direct tension ; the former was the more likely, and the adhesive area called into play would be $4\frac{1}{2}\ (4\frac{1}{2} \times 4 + 4 \times 3) = 135$ square inches, and $\frac{6264}{135} = 46$ pounds per square inch, which would be well resisted by cement mortar, 1 to 1 (see tables).

He hoped Mr. Jones would complete his experiment by building up the tank and filling it with water until it failed.

Mr. Shellshear also appeared to think that retaining walls should not be reduced on account of the adhesive strength of the mortar, and introduced the question of foundations. Now, a large number of retaining walls failed on account of the defective foundations, by sliding forward bodily, and by yielding to excessive pressure on the outer toe, although they would have had sufficient strength and stability had the foundations been sound. By reducing the thickness of a wall we undoubtedly increased the pressure on the outer toe, and developed tensile stress on the inner toe, so that the design of retaining walls must be considerably influenced by the nature of the foundations. But these objections did not apply to solid rock foundations nor to any case where proper foundations existed or had been provided for independently of the wall which was built upon them.

He did not, however, wish it to be understood that he recommended the reduction of the thickness of the retaining walls to such an extent as to develop the full adhesive resistance of the mortar on the inner toe, but rather that a certain value should be taken as the safe adhesive strength of the mortar used in building the wall, and that the thickness at the base should be such as to insure the tensile stress on the inner toes never exceeding the amount.

TABLE I.

TENSILE STRAIN REQUIRED TO SEPARATE BRICKS CEMENTED TOGETHER IN BLOCKS OF FOUR, WITH PORTLAND CEMENT AND LIME MORTARS, AT END OF TWELVE MONTHS.

Description of Brick.	Average steength by compression per brick in tons.	DIMENSION IN INCHES.						Weight in lbs.		TENSILE STRAIN IN LBS.									Set in Air or Water.
					Area.					Portland Cement and Sand.						Lime and Sand.			
		Length.	Breadth.	Thickness.	Bed.	Edge.	Cubical Contents.	Dry.	Wet.	Neat.	1 to 1	2 to 1	3 to 1	4 to 1	5 to 1	1 to 2 Blue Lias.	1 to 2 Dorking	1 to 2 Chalk.	
		ins.	ins.	ins.	ins.	ins.	ins.												
Gault Clay. Pressed ...	40.04	8-75	4-125	2-75	36-09	24-06	99-25	5-13	6-47	1631-4	1576-4	871	988-2	735-2	br'ke in	1448	1520-5	638.7	Air
										1673-4	1642	1708	1264	7503	drilling				W'ter
Gault Clay Wire Cut	32.70	9-00	4-125	2-75	37-125	24-75	102-09	5-86	6-85	2400	1558-3	not set	1037	791	772	not set	not set	679.4	Air
										1679	1408-3	not set	not set	not set	not set				W'ter
Gault Clay, Perforated	46.40	9-00	4-375	2-625	39-375	24-625	103-48	4-95	5-76	3898-8	2982	2231-6	1663-2	1088-6	812-6	1763-0	1349-3	547.0	Air
										3011-0	2721	1834-4	1561-4	933-2	641				W'ter
Suffolk ...	34.94	9-00	4-5	2-625	40-5	23-625	106-3125	6-18	7-14	3275-2	2346	2247	2030-6	1930-6	1337	2372	1788-2	428.6	Air
										3231	2484	2238	1934-4	1869	1154-2				W'ter
Stock ...	38.74	9-00	4-125	2-625	37-125	23-125	97-45	5	5-57	2816-8	2264	1571-8	1516-2	825-8	792-6	1210-6	1479-3	423.8	Air
										3445	2455	2009	1580-8	1259 6	845-6				W'ter
Fareham...										4538	2990	2064	1499	1236	1040	1919-0	1743-0	449.0	Air
Red	90.4	8-75	4-125	2-625	36-01	22-97	94-74	6-55	7-52	4449-0	2237	1917	1128	1145	653				W'ter
Staff'rdsh'e Blue Pres'd with frog	111.04	8-75	4-125	2-75	36-09	24-06	99-25	7-52	7-90	2563-4	2008-4	1844	1535	1183	752	1102-7	1330-6	not set	Air
										2749	1329	1304	1053	1016	718				W'ter
Staff'rdsh'e BlueRough wit'out frog	117.92	8-75	4-125	2-75	36-09	24-06	99-25	7-75	7-81	1744-4	1701-6	1746	1299-6	988	not set	1269-6	1030-8	not set	Air
										1451	1048-2	1186	1090	843	not set				W'ter

Table II.

ADHESION OF MORTAR TO BRICKS, 3 BRICKS SET AS IN FIGURE 1, MORTAR 7 DAYS OLD.

No.	Description.	Size of each Joint.	Area of each Joint.	Area of Two Joints.	Total Force Pounds.	Force per Square inch two Joints.	Mean Force per Square inch two Joints.	Force per Square inch one Joint.	Mean Force per Square inch one Joint	Relative Adhesiveness neat Cement = 1.	Remarks.
1	Neat Cement ..	4·55x4·25	19·33	38·66	2200 (1)	76·95	82·42	153·90	164·84	1·0000	The Brick sheared as well the Joint.
2		4·55x4·20	19·11	38·22	3750 (2)	98·11		196·22			
3		4·55x4·3	19·56	39·12	2150 (1) / 3500 (2)	72·22		144·44			
4	Crushed Sandstone and Cement 1 to 1	4·7 x4·2	19·74	39·48							Failed one after the other.
5		4·5 x4·3	19·35	38·70	2500	64·60	66.15	129·20	132·30	0·8025	
6		4·5 x4·35	19·57	39·14	2650	67·70		135·40			
7	Crushed Sandstone and Cement 2 to 1	4·5 x4·25	19·125	38·25	950	24·83	24·13	49·66	48·26	0·2927	„
8		4·55x4·25	19·33	38·66	875	22·63		45·26			
9		4·6 x4·25	19·55	39·10	975	24·93		49·86			
10	Crushed Sandstone and Cement 3 to 1	4·5 x4·25	19·125	38·25	215 (1) / 1075 (2)	16·86	15·01	33·72	30·02	0·1821	do. do.
11		4·6 x4·25	19·55	39·10	550	14·06		28·12			do. do.
12		4·6 x4·35	20·01	40·02	430 (1) / 700 (2)	14·11		28·22			do. do.
13	Crushed Sandstone and Cement 4 to 1	4·55x4·3	19·56	39·12	350 (1) / 400 (2)	9·58	6·64	19·16	13.28	0·0805	do. do.
14		4·55x4·25	19·33	38·66	200	5·17		10·34			do. do.
15		4·55x4·25	19·33	38·66	200	5·17		10·34			
16	Bluestone Dust and Cement 1 to 1	4·55x4·3	19·56	39·12	1850	47·29	41·48	94·58	82.96	0·5032	do. do.
17		4·45x4·2	18·69	37·38	2000	53·50		107·00			do. do.
18		4· 6x4·25	19·55	39·10	1100 (1) / 750 (2)	23·65		47·30			do. do

19	Bluestone Dust	4·5x4·2	18·90	37·80	1200	31·74	27·91	63·48	55·82	0·3386	do. do.
20	and Cement	4·5x4·25	19·125	38·25	1000	26·14		52·28			do. do.
21	2 to 1	4·55x4·25	19·33	38·66	1000	25·86		51·72			do. do.
22	Bluestone Dust	4·55x4·3	19·56	39·12	550	14·05	14·84	28·10	29·68	0·1800	do. do.
23	and Cement	4·5x4·3	19·35	38·70	500	12·92		25·84			do. do.
24	3 to 1	4·55x4·3	19·56	39·12	575 (1) 800 (2)	17·57		35·14			do. do.
25	Bluestone Dust	4·5x4·2	18·90	37·80	675	17·85	15·28	35·70	30·56	0·1853	do. do.
26	and Cement	4·6x4·15	19·09	38·18	425	11·13		22·26			do. do.
27	4 to 1	4·5x4·2	18·90	37·80	575 (1) 700 (2)	16·86		33·72			do. do.
28	Nepean River Sand	4·55x4·2	19·11	38·22	1550	40·55	56·62	81·10	113·24	0·6869	do. do.
29	and Cement	4·55x4·25	19·33	38·66	2900	75·01		150·02			do. do.
30	1 to 1	4·55x4·25	19·33	38·66	1700 (1) 2500 (2)	54·31		108·62			do. do.
		4·55x4·25	19·33	38·66	950	24·57	18·21	49·14	36·42	0·2209	do. do
31	Nepean River Sand	4·5x4·25	19·125	38·25	300 (1) 650 (2)	12·41		24·82			do. do.
32	and Cement				650 (1)						
33	2 to 1	4·55x4·2	19·11	38·22	700 (2)	17·66		35·32			do. do.
		4·5x4·25	19·125		300		9·89	15·68	18·42	0·1117	after the other.
34	Nepean River Sand	4·55x4·25	19·33	38·66	375 (1) 650 (2)	13·25		26·50			One Brick
35	and Cement										was broken
36	3 to 1	4·55x4·2	19·11	38·22	250	6·54		13·08			off in carting
		4·6x4·3	19·78	39·56	200	5·05		10·10			to University
37	Nepean River Sand	4·6x4·3	19·78	39·56	150 (1) 300 (2)	5·68	4·97	11·36	9·94	0·0603	the other
38	and Cement										stood 300
39	4 to 1	4·55x4·25	19·33	38·66	50 (1) 275 (2)	4·20		8·40			lbs.

Table III.

ADHESION OF MORTAR TO BRICKS.

Two Bricks set as in Figure 2, Mortar 7 days old.

No.	Description of Materials.	Size of Joint.	Area of Joint.	Total Force. Pounds.	Force per Square Inch	Mean Force per Square Inch	Relative Adhesiveness. Neat Cement =1	Remarks.
40	Neat Cement ...	4·50 x 4·25	19·125	3,650	190·84	171·04	1·1000	
41		4·5 x 4·3	19·35	3,100	160·20			
42		4·5 x 4·25	19·125	3,100	162·09			
43	Crushed Sandstone and Cement, 1 to 1	4·6 x 4·2	19·32	2,100	108·69	102·52	0·5993	
44		4·55 x 4·25	19·33	2,000	103·46			
45		4·5 x 4·25	19·125	1,825	95·42			
46	Crushed Sandstone and Cement, 2 to 1	4·55 x 4·3	19·56	1,350	69·01	57·25	0·3347	
47		4·5 x 4·3	19·35					
48		4·6 x 4·3	19·78	900	45·50			
49	Cruched Sandstone and Cement, 3 to 1	4·5 x 4·3	19·35	425	21·96	22·8	0·1334	
50		4·5 x 4·3	19·35	650	33·59			
51		4·5 x 4·3	19·35	250	12·91			
52	Crushed Sandstone and Cement, 4 to 1	4·5 x 4·3	19·35	450	23·25	19·27	0·1126	
53		4·55 x 4·3	19·56	350	17·89			
54		4·5 x 4·25	19·125	300	15·68			

55	Bluestone Dust and Cement, 1 to 1	4·5 x 4·2	18·90	1,450	76·19	75·06	0·4388
56		4·5 x 4·25	19·125	1,700	88·88		
57		4·5 x 4·25	19·125	1,150	60·13		
58	Bluestone Dust and Cement, 2 to 1	4·5 x 4·3	19·35	750	38·75	38·62	0·2257
59		4·50 x 4·25	19·33	750	38·79		
60		4·55 x 4·3	19·56	750	38·34		
61	Bluestone Dust and Cement, 3 to 1	4·5 x 4·3	19·35	700	36·17	38·92	0·2275
62		4·5 x 4·25	19·125	850	44·44		
63		4·5 x 4·3	19·35	700	36·17		
64	Bluestone Dust and Cement, 4 to 1	4·55 x 4·2	19·11	300	15·69	16·12	0·0942
65		4·5 x 4·25	19·125	275	14·37		
66		4·55 x 4·2	19·11	350	18·31		
67	Nepean River Sand and Cement, 1 to 1	4·55 x 4·2	19·11	2,050	107·27	91·49	0·5349
68		4·5 x 4·3	19·35	1,900	98·19		
69		4·55 x 4·3	19·56	1,350	69·01		
70	Nepean River Sand and Cement, 2 to 1	4·5 x 4.25	19·125	800	41·83	39·47	0·2307
71		4·55 x 4.2	19·11	550	28·78		
72		4·5 x 4·3	19·35	925	47·80		
73	Nepean River Sand and Cement, 3 to 1	4·5 x 4·25	19·125	450	23·52	21·06	0·1231
74		4·55 x 4·25	19·33	425	21·98		
75		4·6 x 4·3	19·78	350	17·69		
76	Nepean River Sand and Cement, 4 to 1	4·55 x 4·25	19·33	200	10·34	7·75	0·0453
77		4·55 x 4·25	19·33	100	5·17		
78		4·5 x 4·3	19·35	150	7·75		

Table IV.

ADHESION OF MORTAR TO BRICKS, 3 BRICKS SET AS IN FIGURE 1, MORTAR 28 DAYS OLD.

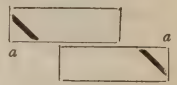
No.	Description.	Size of each Joint.	Area of each Joint.	Area of Two Joints.	Total Force Pounds.	Force per Square inch two Joints.	Mean Force per Square inch two Joints.	Force per Square inch one Joint.	Mean Force per Square inch one Joint	Relative Adhesiveness neat Cement = 1.	Remarks.
79	Neat Cement ..	4·55x4·1	18·65	37·30	4300	115·28	1 03·04	230·56	206·8	1·0000	
80		4·55x4·25	19·33	38·66	3100 1 4000 2	91·82		183·64			
81		4·55x4·2	19·11	38·22	3900	102·04		204·08			
82	Crushed Sandstone and Cement 1 to 1	4·5 x4·25	19·33	38·66	2000 1 2800 2	62·07	59.43	124·14	118·86	0·5767	In No. 82 the brick broke across without shearing of joint.
83		4·5 x4·2	18·90	37·80	1700 1 3000 2	62·16		124·32			
84		4·55x4·27	19·42	38·84	1900 1 2300 2	54·06		108·12			
85	Crushed Sandstone and Cement 2 to 1	4·6 x4·3	19·78	39·56	1250	31·59	33·89	63·18	67·78	0·3288	In the experiments 82 to 93 and 106 to 117 the joints were sheared off separately.
86		4·5 x4·2	18·90	37·80	1200 1 1600 2	37·03		74·06			
87		4·5 x4·22	18·90	37·80	1150 1 1350 2	33·06		66·12			
88	Crushed Sandstone and Cement 3 to 1	4·6 x4·25	19·55	39·10	700 1 1050 2	22·37	24·01	44·74	48·02	0·2330	In No. 87, for example, one joint was sheared off at 1,150 and the other at 1,350.
89		4·5 x4·25	19·125	38·25	900	23·52		47·04			
90		4·55x4·2	19·11	38·22	1000	26·16					
91	Crushed Sandstone and Cement 4 to 1	4·5 x4·2	18·90	37·80	750 1 760 2	19·97	22·75	39·94	45·50	0·2207	In experiment No. 89 the joints yielded one after the other.
92		4·55x4·2	19·11	38·22	1050	27·47		54·94			
93		4·5 x4·2	18·90	37·80	675 1 900 2	20.83		41.66			

94	Bluestone Dust and Cement 1 to 1	4·55x4·2	19·11	38·22	2400	62·79	61·89	125·58	123.78	0·6006	In this case the two joints appeared to yield at the same time.
95		4·6 x4·2	19·32	38·64	2100 } 1	64·69		129·38			
96		4·5 x4·2	18·90	37·80	2900 } 2	58·20		116·40			
					2200						
97	Bluestone Dust and Cement 2 to 1	4·55x4·25	19·33	38·66	2100	54·31	45·33	108.62	90·66	0·4399	Here the joints yielded one after the other.
98		4·55x4·27	19·42	38·84	1700	43·76		87·52			
99		4·55x4·2	19.11	38·22	1450	37·93		75·86			
100	Bluestone Dust and Cement 3 to 1	4· 5x4·2	18·90	37·80	1000 } 1	30·42	27·13	60.84	54·26	0·2632	do. do.
101		4· 5x4·25	19·125	38·25	1300 } 2	23·52		47.04			do. do.
102		4·55x4·2	19·11	38·22	900	27·47		54.94			do. do.
					750 } 1						
					1350 } 2						
103	Bluestone Dust and Cement 4 to 1	4· 6x4·2	19.32	38·64	750 } 1	21·02	24·34	42.04	48·68	0·2362	do. do.
104		4·55x4·3	19·56	39·12	875 } 2	25·56		51.12			Both joints appeared to yield at the same time.
105		4· 5x4·2	18·90	37·8	1000	26·45		52.90			
106	Nepean River Sand and Cement 1 to 1	4·55x4·25	19·33	38·66	1950 } 1	62·72	54·99	125.44	100·98	0·5331	do. do.
107		4·55x4·25	19·33	38·66	2900 } 2	55·61		111.22			do. do.
108		4·55x4·3	19·56	39·12	2150	46·65		93.30			Failed one after the other.
					1650 } 1						
					2000 } 2						
109	Nepean River Sand and Cement 2 to 1	4·5 x4·25	19.125	38·25	900	23·52	20·51	47.04	41·02	0·1990	do. do.
110		4·55x4·2	19·11	38·22	350 } 1	17·06		34.12			do. do.
111		4· 6x4·15	19·09	38·18	950 } 2	20·95		41.90			do. do.
112	Nepean River Sand and Cement 3 to 1	4· 6x4·25	19·55	39·10	800	14·06	14·56	28.12	29.12	0·1413	do. do.
113		4· 6x4·3	19.78	39·56	400 } 1	15·16		30.32			do. do.
114		4·55x4·25	19·33	38·66	700 } 2	14·48		28.96			do. do.
					600						
					420 } 1						
					700 } 2						
115	Nepean River Sand and Cement 4 to 1	4· 6x4·2	19·32	38·64	250	6.47	5·76	12.94	11·52	0·0559	do. do.
116		4·55x4·25	19.33	38·66	300	7·75		15.50			do. do.
117		4·55x4·3	19·56	39·12	120			6.12			

TABLE V.

ADHESION OF MORTAR TO BRICKS.

Two Bricks set as in Figure 2, Mortar 28 days old.

No.	Description	Size of Joint.	Area of Joint.	Total Force. Pounds.	Force per Square Inch	Mean Force per Square Inch	Relative Adhesiveness. Neat Cement=1	Remarks.
118	Neat Cement	4·55 x 4·25	19·33	3,700	191·41	220·76	1·0000	The brick broke with 3250 thus— 
119		4·5 x 4·2	18·90	4,800	253·96			
120		4·5 x 4·2	18·90	4,100	216·93			
121	Crushed Sandstone and Cement, 1 to 1	4·55 x 4·15	18·88	3,600	190·67	172·09	0·7795	
122		4·55 x 4·2	19·11	3,100	162·21			
123		4·55 x 4·17	18·97	3,100	163·41			
124	Crushed Sandstone and Cement, 2 to 1	4·5 x 4·2	18·90	1,700	89·94	78·23	0·3543	
125		4·55 x 4·2	19·11	1,400	73·26			
126		4·55 x 4·15	18·88	1,350	71·50			
127	Crushed Sandstone and Cement, 3 to 1	4·55 x 4·2	19·11	800	41·86	36·64	0·1659	These results appear to be inaccurate.
128		4·55 x 4·25	19·33	600	31·03			
129		4·5 x 4·2	18·90	700	37·03			
130	Crushed Sandstone and Cement, 4 to 1	4·5 x 4·2	18·90	1,000	52·91	64·81	0·2935	
131		4·5 x 4·3	19·35					
132		4·5 x 4·2	18·90	1,450	76·71			

133	Bluestone Dust and Cement, 1 to 1	4·5 x 4·15	18·67	2,560	137·11	148·26	0·6715	
134		4·55 x 4·15	18·88	2,650	140·36			
135		4·5 x 4·25	19·125	3,200	167·32			
136	Bluestone Dust and Cement, 2 to 1	4·55 x 4·2	19·11	1,500	78·49	77·39	0·3505	
137		4·55 x 4·2	19·11	1,400	73·26			
138		4·55 x 4·1	18·65	1,500	80·42			
139	Bluestone Dust and Cement, 3 to 1	4·5 x 4·2	18·90	750	39·68	35·14	0·1591	
149		4·5 x 4·2	18·90	650	34·39			
141		4·5 x 4·25	19·125	600	31·37			
142	Bluestone Dust and Cement, 4 to 1	4·6 x 4·25	19·55	600	30·69	32·77	0·1484	
143		4·5 x 4·25	19·125	700	36·60			
144		4·55 x 4·25	19·33	600	31·03			
145	Nepean River Sand and Cement, 1 to 1	4·5 x 4·15	18·67	2,000	107·12	100·75	0·4563	Brick sheared at Joint.
146		4·55 x 4·25	19·33	1,650	85·35			
147		4·5 x 4·25	19·125	2,100	109.80			
148	Nepean River Sand and Cement, 2 to 1	4·6 x 4·27	19·64	1,100	56.00	48·17	0·2182	
149		4·55 x 4·25	19·33	700	36·21			
150		4·55 x 4·2	19·11	1,000	52·32			
151	Nepean River Sand and Cement, 3 to 1	4·55 x 4·2	19·11	400	20·93	19·11	0·0865	
152		4·55 x 4·25	19·33	350	18·10			
153		4·55 x 4·2	19·11	350	18·31			
154	Nepean River Sand and Cement, 4 to 1	4·55 x 4·2	19·11	300	15.69	17·43	0·0789	
155		4·55 x 4·2	19·11	300	15·69			
156		4·55 x 4·2	19·11	400	20·93			

TABLE VI.

SUMMARY OF RESULTS DETAILED IN TABLES II., III., IV., AND V.

Description of Materials.	Mean Adhesive Strength in Pounds per Square Inch after 7 days.	Mean Adhesive Strength in Pounds per Square Inch after 28 days.
Neat Cement	168	213
Crushed Sandstone and Cement, 1 to 1	117	146
Do. do. 2 to 1	53	73
Do. do. 3 to 1	26	48
Do. do. 4 to 1	16	45
Bluestone Dust and Cement, ... 1 to 1	79	136
Do. do. ... 2 to 1	47	84
Do. do. ... 3 to 1	34	45
Do. do. ... 4 to 1	23	41
Nepean River Sand and Cement, 1 to 1	102	105
Do. do. 2 to 1	38	45
Do. do. 3 to 1	20	24
Do. do. 4 to 1	9	14

TABLE VII.

TENSILE STRAIN.—1″ x 1″ Briquettes mixed with "L" ("Castle") Cement and different kinds of Sand, in the proportion of 3 to 1 by weight.

No.	Description of Sand used.	Quantity of Water.	Tensile Strain in Pounds per sq. in. At 3 days.	At 7 days.	At 28 days.
1	*Sand* obtained from *Crushed Sandstone*, as used in the tests	10 %	104	191	219
2	*Yellow Sand* from Dowling Street	7½ %	43	177	215
3	*White Sand* from Dowling Street	7½ %	132	183	219
4	*Nepean River Sand*, (residue on 900-mesh sieve—57½ per cent.)	7½ %	123	182	232
5	*Do.* *do.* (passed through 400 and caught on 900-mesh sieve)...	7½ %	111	173	234

N.B. In the case of both Nos. 2 and 3 the sand would *all* pass through a sieve of 900 meshes to Square Inch.

10th March, 1887.

W. D. Cruickshank, President, in the Chair.

The following Paper was read by Mr. Shellshear :—

ON THE APPLICATION OF THE CONVERGING JETTY SYSTEM.

For the Removal of Bars from the Entrances to the Rivers of New South Wales, with some remarks upon Hydraulic Dredging.

By Walter Shellshear, Assoc. M. Inst. C.E.

The rapid development of our coasting trade, and the ever-increasing necessity for improving the navigation of our eastern rivers, and thus lessening the risk inseparable from the arduous duties of the mariner, has induced the author, at the request of several members of the Association, and others who are interested in this important subject, to prepare the following paper. In a communication to the Royal Society of New South Wales, in 1884, the author considered in general terms the principles on which our rivers could be improved, and in the paper read before this Association, on the 8th April, 1886, the construction of breakwaters and training jetties was considered. On the present occasion it is proposed to explain in detail the author's views as to the best plan of applying the converging jetty system to the improvement of the Richmond and Hastings rivers, and also to add a few remarks on hydraulic dredging.

The great importance of the question of improving our river entrances, does not require to be enlarged upon in this paper, for it must be obvious to all that anything that can be done to improve these natural highways to so important a part of our territory, must enhance the value of property, and increase the national wealth.

The first matter to be studied is the cause of the formation of bars at our river entrances. A bar is a ridge or shoal across the navigable channel, at the mouth of a river, over which there is a less depth of water than in the adjacent portions of the channel.

The formation of bars may be attributed to two principal causes :—

(1) The tendency of the sea, or of waves driving along the shore by the prevailing winds, or of littoral currents, to heap up the beach in a continuous line along the shore, and close up the outlet of the river, which is only partially prevented by the scour of the tidal ebb and flow, and the discharge of inland waters.

(2) The deposit of material brought down by a river, when the velocity of the river is checked on entering the sea.

The formation of bars at the mouths of tidal rivers is mainly due to the first cause, whilst the action of the second cause is most clearly manifested at the deltas of rivers flowing into tideless seas.

The tendency of the waves to heap up the beach in a continuous line along the shore is well illustrated in the case of all our coast rivers. Thus at every inlet we see sand spits pushing across the entrance, and the direction of these sand spits is either north or south, according to the amount of protection they receive from the adjacent headlands. Thus at the Richmond River the tendency is for the sand spit to push to the north, by the action of the southerly wind, there being no headland to the south of the entrance. At the Clarence, the Hastings, the entrance to Lake Macquarie, and other entrances which are well protected on the south, we see the sand spits pushing southwards, by the action of the north-east winds.

Examining the charts of the coast of New South Wales, we see that the bar formation is merely local, and is confined to a tolerably narrow ridge across the entrances to the rivers, the depth rapidly increasing seawards, and at most places a depth of ten fathoms is reached within half a mile from the shore. This feature is of great importance in connection with the question of

removing the bars, for it shows that if the bars could once be moved, there would be but little prospect of their re-forming, as is almost invariably the case when it is attempted to remove a bar from a river entrance where the sea is shallow for a great distance from the shore.

Of the different systems of improving river entrances, the converging jetty system has proved more uniformally successful than any other system; and there are few rivers in the world that offer greater facilities for the successful application of this system than the rivers of New South Wales.

In considering any scheme for lowering or removing bars, the following points must be kept in view:—Firstly, that, although as a rule the sea along the coast of New South Wales is moderately smooth, yet at times storms of considerable violence occur. Secondly, the necessity of making provision for the proper discharge of flood waters under the exceptional characteristics of the country, as all the rivers are liable to floods of considerable magnitude. And lastly, the *sine quâ non* that the cost of carrying out the proposed works must be kept down to the lowest possible figure.

The object aimed at in the construction of training jetties is, to concentrate the tidal and upland water flow in a definite channel, and to protect the channel from the inroads of sand as it tends to push its way across the entrance by the action of the waves.

The rise and fall of tide along the coast is from three to five feet, and although this is only a moderate range, most of the rivers have a large tidal capacity, and the amount of tidal water entering and leaving the rivers is quite sufficient to maintain a good channel over the bars if the flow was well directed by judiciously planned works; and many examples of successful training works could be cited where the range of tide is even less than the range available in the case of our rivers.

The quantity of fresh water coming down the rivers is very variable. At times the rivers almost cease to flow, whereas in times of flood they bring enormous volumes down to the sea. Some estimate of this variation may be made when it is mentioned

that the average rainfall for the coast district is something like 35 inches per annum, and this large amount is made up by a comparatively few days of excessive rain, followed by weeks, and even months of complete drought.

No general plan for improving our rivers could be given, as each case has to be dealt with according to its local characteristics. But to illustrate how the jetty system could be applied to our rivers, two very different cases will be considered. Firstly, the Richmond River (Plate 1), where the entrance is exposed to the full force of the southerly weather, and has only slight protection on the north. And secondly, the Hastings River (Plate 2), where the entrance is well protected on the south, but is exposed to the north-easterly weather.

The Richmond River (Plate I.) is a typical one, and perhaps no better example could be taken from the list of Australian rivers. This river rises on the Queensland border, and the main river, exclusive of its many branches, has a course of about 150 miles. The area of the watershed is about 2,660 square miles, and it falls into the Pacific Ocean. Its entrance is obstructed by one of the most dangerous bars on the coast, and has been the scene of a large number of shipping disasters; in fact, this entrance might appropriately be called a cemetery of wrecks. This river flows through one of the richest agricultural districts in the colony. The district is noted for its magnificent sugar cane plantations; and, from the great extent of splendid volcanic soil, there is every reason to expect that in a few years it will take one of the first places among the agricultural centres of New South Wales. There are also good indications of abundant mineral wealth in the district. The improving townships of Casino, Lismore, Coraki, Woodburn, Ballina and several others are on its banks. The main river is navigable for coasting vessels of light draught as far as Lismore—seventy-five miles from the entrance—and at present two lines of regular steamers run weekly trips to and from Sydney, in addition to a number of sailing vessels engaged in the timber trade. The entrance within late years has shifted through a range of about 6,000 feet. The navigable

channel is constantly shifting, and at times the crossing is so bad that ships have repeatedly had to wait for weeks before they could cross in or out. The present channel is under the North Head, and is very narrow and tortuous. The bar is formed of fine white sand, easily set in motion by the current or waves, and to the north there are several patches of rock in the estuary. A branch of the river, called the North Creek, joins the main stream almost at the entrance, and the effect of the waters flowing from this branch must be taken into consideration in setting out any plan for improvement works. All the circumstances of the case point to the suitability of the converging jetty system for effecting permanent improvement to this entrance. The position marked in the detailed chart (Plate I.) appears to possess special advantages, for the reasons that the position of the proposed channel is so placed that the combined flood and tidal waters from the main channel and the subsidiary, or North Creek, have a straight run, and therefore their scouring action would have the maximum effect in deepening and maintaining the channel. The dangerous rocks near the North Head would be avoided; the entrance being nearly at right angles to the coast, the extent of bar to be acted upon is a minimum; and, lastly, the adoption of the curved form of jetties would deflect the current into the centre of the channel, and prevent the undermining of the works in times of heavy floods. This form of entrance, moreover, possesses in a marked degree the properties of a nozzle, and give the ebb tide and flood waters the best effect in deepening the centre of the channel and concentrating the scour of the issuing current on the bar.

The entrance to the Richmond River is in some respects similar on a small scale to the entrance to the Charleston Harbour, on the east coast of the United States, and the lines above proposed for the improvement works at the Richmond are similar to those at Charleston, where a very marked improvement has been effected by converging jetties, and every year since the commencement of these works the improvement in the channel has become more marked. The rise and fall of tide at Charleston is only slightly more than at the Richmond, and the two places are about equally

exposed to the force of the sea, the Richmond has the great advantage however, that the sea is much deeper near the coast than is the case at Charleston, a depth of 10 fathoms being reached within half a mile of the shore line at the Richmond, whereas that depth is not reached for several miles in the case of Charleston. The tidal capacity of the Richmond is very considerable, and the large volume entering and leaving the river at every tide should be more than enough to maintain the entrance if its energy was well directed, without the assistance of the upland waters which are of themselves an important factor in connection with the scouring out of the bar. Having thus described what appears to the author the best lines on which to construct improvement works for the Richmond entrance, it is next proposed to consider the case of the Hastings River and then proceed to the question of the most suitable method of constructing training jetties with the material and labour available in this Colony.

The Hastings River (Plate 2) rises in the mountains about forty-five miles from the coast and after following a circuitous course receiving on its way to the sea numerous tributaries, falls into the ocean at Port Macquarie, the area of its water shed is about twelve hundred square miles. The river as it approaches the ocean takes a northerly direction and then an abrupt turn to the south widening out into a broad sheet of shallow water, turning eastwards as it enters the ocean at Port Macquarie. The entrance to this river unlike the Richmond is well protected by nature from the southerly weather and the variation in its entrance channels are caused by the action of the north easterly weather, in this case the rocky South Head on which the town of Port Macquarie is built, forms a natural protection work extending into deep water on the side from which the heaviest weather breaks on the coast, all that is required therefore is the construction of a training jetty from the northern sand spit in an easterly direction, to protect the entrance from the inroad of sand from the north, and to permanently fix the channel so that the tidal action may be concentrated and used to the best advantage in clearing and maintaining a fixed channel; after a careful study of the tidal

capacity of the river and taking into consideration the position of the outlying rocks on the south side, the most suitable position for the northern jetty in the author's opinion is that shown on the detailed chart of the entrance.

The next question to be considered is the best method of constructing training jetties: the author has already described at some length the various systems of constructing training jetties in a previous paper, and it is now proposed to describe what in his opinion is the most economical method of construction in the case of our rivers. In connection with this point the following considerations must be borne in mind. Firstly, the fineness of the sand renders it absolutely necessary that the site of the jetties should be protected for a considerable distance in advance of the works whilst in progress, otherwise the scouring current round the end of the advancing works would cause such changes in the bottom that vast quantities of material would be wasted in filling up the holes and trenches scoured out by this action. Two plans of protecting the bottom at the site of works of this class have been successfully used in other parts of the world. The first is to pave the site with small stone thrown in from a staging or from barges, and distributed evenly over the bottom to the depth of two or three feet for a considerable width on either side of the centre line of the works. The second is by the use of fascine mattresses. The works at the Sulina mouth of the Danube, and the breakwaters at the entrance of the Amsterdam ship canal, are good examples of the first method, and the jetties at the Charleston Harbour and the mouth of the river Maas are good examples of the second plan.

Either of these plans could be used with advantage on our coast, but the price of labour, and the probable difficulty of getting suitable material would militate against the use of the fascine mattresses. A paving of stone would therefore appear to be the best for our case. In the construction of training jetties, the rate of progress is a question of importance, for the more rapidly the works can be pushed forward the less will be the effect of temporary local changes on the site. From this fact, and also from

the circumstance that timber of great strength and considerable durability is abundant on all the eastern rivers, a modification of the ngenious system of construction employed by Sir Charles A. Hartly at the Sulina Mouth of the Danube seems peculiarly suitable.

The force of the sea being greater in the case under consideration, a greater height for the platform would be necessary, and in the more exposed parts of the works it would be advisable to cut off the sheet piling at about half tidal mark, so that the crests of the waves in times of storm might pass over without bringing an undue shock on the works. The back lash of the waves being most injurious to the rubble foundations where a solid structure is taken up above high water mark, and as the jetties under consideration are for the purpose of directing and concentrating the tidal currents rather than for the complete breaking up of the waves, their efficiency would not be impaired by a reduction in height of the solid part of the works; moreover, by cutting off the sheet piling at the height proposed, relief would be furnished in times of floods and exceptionally high tides; and at the same time the best effect of the tidal scour from the latter half of the ebb would be retained. No doubt a considerable quantity of sand would be thrown over the works in times of storm, but the well-directed ebb current would be more than able to roll this out to sea, where beyond the jetties it would encounter the littoral ebb-current, and be moved from the entrance with a velocity accelerated by the storm.

The figure (Plate 3) shows the construction of the form of jetty proposed. The method of construction would be as follows: The open work of the jetty would be urged forward as rapidly as possible, the piles being protected by a paving of small stones spread over the bottom for about thirty feet on each side of the centre line. This material could be deposited either from barges or by a travelling crane from the pier. By a suitable pile engine, each succeeding bay of piling could be driven from the end of the completed pier; and as the open work progresses the sheeting could be advanced and the necessary protecting rubble deposited. After a time, when the rubble mound had become well

consolidated, which would be greatly helped by oysters, coral, and other calcarious insects, the works could, like those at the Danube, be rendered permanent with a concrete top at a moderate cost. It would be necessary to protect the rubble mound in the more exposed portions of the works by depositing large blocks of stone or concrete on the slope, but the extent to which this would be necessary could be settled as the works progressed.

The last part of my subject will now be considered, namely, Hydraulic Dredging.

The economical removal of sand from the entrance channels of our rivers is a very important question, for if the sand could by any means be removed it would often afford great assistance to the navigation, even if the circumstances of the port did not warrant a large expenditure on permanent works; the system of bucket-dredging, so useful in the upper parts of a river, and for deepening the interior of a harbour, is too slow and costly for the work under consideration, and the question naturally arises, is there no other system that could be used in cases like that under discussion? As pointed out in the earlier part of this paper, the bar formation at the entrances to our rivers is confined to a tolerably narrow ridge at the entrance to the rivers, and that deep sea water is found at a very short distance from the shore, it therefore follows that if during the periods of ebb tide the sand in the entrance channel could be set in motion, much of it would be carried away into deep water, and for a time at least would not obstruct the navigation. It is obvious that without protection works this deepening process would not be permanent, but even temporary improvements would be of great value in opening up the port after a heavy storm, when the depth over the bar had been reduced so as to obstruct navigation. Within the last few years the Americans have devoted much attention to the question of removing shoals and sand banks by hydraulic scour, and it is proposed to describe one or two of the plans adopted.

Major T. M. Mansfield, of the United States, invented a very useful Hydraulic Excavating Machine (Plate III.), a full account of which is published in the annual report of the Chief of

Engineers of the United States Army for 1884, page 1302. This machine consists of an ordinary screw steamer, fitted up with a powerful set of pumps and a kind of hydraulic raker; this is connected to the pumps by suitable flexible pipes, and is hung over the stern of the steamer by a pair of shear legs. Each of the branches of the rake is fitted with a nozzle, which direct a powerful jet of water against the bottom. The methed of working this apparatus is as follows:—The steamer is anchored by cables on lines running aft from the bow on both sides for a distance, say 1000 feet, each of which lines should be provided with two anchors connected as shown on the figure. Two cables are also passed forward from the bow and anchored as shown. By this arrangement the steamer is pivoted, as it were, at the bow, and by means of the rudder at the stern it may be made to travel on an arc whose chord is the desired width of channel. When the steamer is placed in position, and the anchors placed as above described, the stern of the steamer being down stream, the water jet or hydraulic rake is turned on, and the propeller started to go ahead, the rudder being alternately turned to port and starboard. The water jet disturbs the material at the bottom, which is thoroughly mixed with the water by the combined action of the propeller and water jets, and is sent seaward by the ebb current, assisted by the current produced by the propeller; the steamer is gradually hauled back by the stern cables, and a channel is rapidly cut through the sand bank. This form of dredging machine, besides being simple in construction and most effective in operation, is specially adapted to the removal of river bars when the material is to be transported short distances to the pools below, but more especially is it adapted for service upon exposed ocean bars, where the sea is rough and where the ordinary form of dredger is inapplicable. Very effective work can be done by simply mooring a screw steamer in the way above described and trimming her a little by the stern, so as to get the propeller shaft slightly inclined, and setting the propeller ahead, slowly drawing the vessel astern by the stern cables, at the same time moving the stern from side to side by the action of the rudder.

This method of dredging—or, as it is more properly called, propeller-sluicing—has been used in America with great success. In a recent volume of the "Minutes of the Institution of Civil Engineers," Vol. 83, p. 386, the results of some important work are published in a paper by Mr. Harry Harngood, Assoc. M. Inst, C.E. From this paper it appears that at the Saint Helen's bar, on the Columbia River, Oregon, U.S.A., a channel 1,200 feet long, 200 feet wide, was deepened six feet in three days in 1882. When the great depth of the sea at a short distance from the bars at our river entrances is considered, it must be evident how peculiarly suitable this method of sluicing is for temporarily improving the entrance channels; and what great assistance this system of sluicing would afford in securing a permanent channel when used in combination with suitably planned improvement works.

The questions treated of in the foregoing are ones that have been perplexing the colony for some time past, and the devising of some *speedy* and *economical* scheme for opening up the rivers on the banks of which some of the finest land in the colony is to be found, is a much wished for desideratum. The suggestions above are merely thrown out as the outlines of what might be done to dissipate this barrier to the full development of the resources of the country through which the rivers flow.

The fundamental principles the author considers to be kept in view in undertaking works for the removal of bars at the entrance to rivers similarly situated to those on the coast of New South Wales, where a practically unlimited depth of water is found so near the shore, is firstly to take the channel by as straight a course as possible seaward, so that the best effect can be obtained from the ebb tide and flood waters over the line of minimum obstruction,* at the same time protecting the channel from the

* It is interesting to note that during the late floods on our northern rivers the tendency was to cut straight channels through the sand spits, thus showing that when the river currents are at their maximum strength they are able for a time to overcome the action of the waves, and the rivers assume a straight course to sea. From this it must be evident that the most suitable lines for protecting works are those which provide the straightest possible channel to deep water.

inroad of sand from the beach by suitable works extending from shore into the deep water. Secondly, the works should be pushed forward as rapidly as possible, so that the effect of temporary local changes may be reduced; for if this be not done the scouring action at the advancing ends of the jetties will be so great that the cost of the works will be increased to a serious extent. Adequate provision must be made for the entrance of tidal waters, so that the tidal portion of the river may be properly filled at each tide, thus extending the tidal influence as far inland as possible; at the same time this would afford a free exit for the ebb tide and flood waters. As far as possible the lines of the works must be such that the tidal and flood waters will be deflected into the centre of the channel, so that the works will not be undermined.

The regulation of the river immediately above the entrance jetties could be best effected by dykes or groins. The efficiency and economy of this system of regulating channels is well illustrated by many successful applications in Europe and America.

When the growing importance of our coast districts, and the vast area of splendid land which is at present more or less closed by the uncertainty which exists in getting produce to market, and the large amount of property invested in shipping is considered, the question under discussion will be seen to be not merely of local but of national importance, and that any scheme which could be devised to remove the present obstruction to the full development of so important a part of our territory, will confer a lasting benefit on the colony.

That to accomplish this, the author is convinced, is a matter capable of determination by a close investigation of the local circumstances governing their existence and natural features, and an intelligent application of the best means that have been found to operate and overcome somewhat similar difficulties in other parts of the world.

Finally, it must be remembered that the science of harbour engineering is one based on experience, and it is only by a careful study of the works of others that we may hope to profit by their successes, and be warned by their failures.

ADDENDUM.

Some doubts having been expressed as to the strength of the jetties proposed in the paper, it may therefore be of interest to point out that when low level works are constructed the full force of the sea is not developed against the works but the crests of the waves pass over the works without bringing their destructive force into play. The jetties at the mouth of the Mississippi are constructed of willow mattresses weighted down with small stone, and with a row of concrete blocks placed upon the top the jetties rising but little above the ordinary sea level, the effect of a great storm on these jetties, which are certainly not more substantial than those proposed, is thus described in the *Scientific American*, of January 27th, 1887 :—"If a single fact, more than such as we know, was wanted to confirm the confidence now felt in the jetties, the late storm in the Gulf has supplied it. It has often been asked how the jetties would stand one of those overwhelming tempests that sweep over the Gulf at intervals of years. Such a tempest we have recently had, and the jetties came out of the conflict with which the hurricane force assailed them staunch and victorious. The storm went beyond any to which the jetties had been exposed, beyond even the noted hurricane of 1883. Not only did the jetties at the mouth of the Mississippi withstand the might of the storm, but those at the Labini, not half-finished, did the same. They are built on the same system as the Eads' jetties, and the might that held out the storm was the same fragile-looking willow mattresses that are used there. Major Heuer, who has supervision of the work, has carefully examined what effect it has had upon the unfinished work. The New Orleans *Picayune* reports that Major Heuer, '*found the Labini jetties entirely uninjured, and no material change in the depth of the channel between them. They had withstood the fury of a storm that had swept away every human structure upon the adjacent land.*'"

A groin constructed at Newhaven, on the English Channel, extending 500 feet seaward, which was constructed on the beach

of timber piles protected with large masses of chalk and sandstone, withstood the force of the sea for thirty-six years, when it was removed on account of more extensive works being carried out.

The two things that have to be considered in this class of structure are, firstly, that the sand must be kept from getting away by a proper paving of small stone or willow mattresses, and secondly, the works must not be taken up much above the mean sea level, for the higher the solid works are raised the greater the shock with which the waves assail them.

12th May, 1887.

W. D. CRUICKSHANK, President, in the chair.

The following candidate was balloted for and duly elected as :—

MEMBER.

P. B. WALKER.

Mr. J. B. HENSON, then read the following paper :—

THE SANITARY ASPECT OF THE SITE OF THE METROPOLIS AND ITS ENVIRONS.

And hygienic precautions, which should be concurrent with the expansion of the area of population.

By J. B. Henson.

The growth of the metropolis during the last two decades has been very great, and instances are common where public works have been constructed of an extent estimated at the time to be ample for future requirements, but have scarcely been finished before their limited capacities have been perceived and additions demanded; the writer has, therefore, been impressed with the necessity of considering not only the site of the city and its surrounding suburbs, but also the whole area over which it is evident that in the immediate future a large population will be settled. The area under review will include the basins of the Lane Cove, Parramatta, and Cook's Rivers, the upland waters from which will, as population grows denser, become more and more contaminated, and bear an ever increasing amount of filth towards the city. A description of the physical characteristics of the whole area is a necessary preliminary, and will render future remarks more intelligible.

It is well known that the geological and physical features of a district which is a seat of population have an important influence upon the health of the inhabitants. There are many cities and towns which have obtained distinction, because they are situated on very healthy sites, whilst others, on the contrary, are characterized

by the extreme unhealthiness of their location. In these latter instances surprise may be expressed at the choice of the site, but it must be remembered that the requirements of commercial intercourse which promotes the concentration of population, often outweigh all other considerations. This is particularly noticeable in regard to coastal and river towns. The site of a town or city, no matter how unhealthy it may be naturally, may always be improved by the art and skill of man. The improvement may be slight; the expenditure to attain this improvement in the first instance, and maintain it subsequently, may be very heavy—so much so, that another and healthy site, offering less commercial facilities naturally, would for a similar, or, perhaps, even less expenditure on works to overcome this one drawback, be placed on an equal footing in regard to commerce with the former. The concentration of population forming cities and towns is an artificial order of things, and causes many marked changes in the natural condition of the locality and its surroundings. Many of these changes are directly detrimental to the health of the inhabitants, and steps have to be taken to counteract or mitigate their baneful influence. The character of the works necessary to attain this object is largely influenced by the physical conformation of the locality.

The metropolis of New South Wales is noted for its possession of a site which is naturally well adapted to the requirements of a commercial port, and, also taking the site as a whole, its healthiness is above the average. But the advent of population has degraded this latter characteristic, and one of the objects of the writer is to examine this matter and consider the remedies. The site of the metropolis presents many interesting features, scenical and geological, which have attracted a great deal of attention. No remarks are needed in regard to the former, as they are outside the scope of this paper, the latter will therefore now be more particularly described. The geological formation of the whole district is sedimentary, consisting mainly of massive sandstone resting upon the coal measures, and overlaid to a large extent with a comparatively thin capping of clay shales. There are also several drift sand beds and fluviatile mud deposits of recent geological formation, which

must not be overlooked. The stratification as a rule is regular. The natural features of the whole district have been developed by erosive action, which has produced in the sandstone precipitous and rugged outlines and deep gorges, and in the easily weathered shales gentle and regular undulations of the surface. The waters of Port Jackson, including its numerous ramifications, and Botany Bay, lie in deeply excavated hollows in the sandstone rock. A main ridge, extending westerly from the coast at a point almost due east of the city, divides the drainage basin of Port Jackson and the Parramatta River from the drainage basin of Botany Bay and Cook's River.

Upon the northern and southern flanks of this ridge population has settled most densely. Inland, this ridge unites with other main ridges, the first joins on the southern side and extends around the basin of Cook's River in a southerly and easterly direction, terminating on the shore of Botany Bay, opposite the entrance. Much further inland, a main ridge joins on the north and extends northerly, easterly and south-easterly around the combined basins of the Parramatta and Lane Cove Rivers, and terminates opposite the entrance to Port Jackson. The area of the basin of Cook's River is fifty-five square miles, and the area of the Parramatta River basin, including Lane Cove River and other branches, is 167 square miles. The total area of the basins, the drainage water from which disembouges within the metropolitan area, is, therefore, 222 square miles. On the main central ridge the sandstone rocks reach their greatest altitude in the vicinity of the coast, the elevation approaching 300 feet above sea level. From this point going inland the elevation of the sandstone rocks decreases; in the neighbourhood of the city it has fallen to less than 100 feet above sea level, and at Concord, about fifteen miles inland from the coast, the rock disappears below the harbour waters. The clay shales are scarcely noticeable eastward of the city; within the city they are found a few feet in thickness, resting upon the sandstone summits. Going westward, however, they rapidly thicken, and extend over largely increasing areas, until the sandstone wholly disappears as a surface rock, and the shale takes it place.

In a northerly and southerly direction across the centre of the basins, which is a line transverse to the trend of the lines of main drainage, the sandstone is found reaching its greatest altitude at the northern extremity of the northern ridge. At this point, it is capped with clay shale beds, the surface level of which is 600 feet above sea level. From this point, the strata inclines towards the Parramatta River, continues on horizontally towards Cook's River, then rises slightly towards the south. The two recent formations before referred to, viz., the sand beds and mud deposits, have a very important relation to the subject of this paper. The largest of the sand beds is on the northern shore of Botany Bay, and it extends from the Bay northerly to the crest of the main central ridge, and caps it in several places. The next in importance is the sand bed lying between Bondi Bay and Rose Bay; besides these, there are other sand beds of small extent and minor importance. The sand beds are composed of drift sand. The Botany sands extend over an area of about twenty square miles, and they rest partly upon clay shales and partly upon sandstone rock. These underlying strata have been deeply eroded before the deposit of sand took place, and the sand is therefore found to vary in depth from a few feet to over 100 feet, the deepest places being along the course of the former gullies and creeks Portions of these vast sand-beds have been of immense benefit to the city, and deserve more than a passing notice. The Botany sands may be divided into three areas, corresponding to the three streams which flow across them—the Eastern, or Bunnerong Basin, the Central, or Lachlan Basin, and the Western, or Shea's Creek Basin. The Lachlan and Bunnerong basins have been the source from which, until within a few months, the water supply for the city of Sydney and many of its suburbs has been wholly derived. The amount of water drawn from the Bunnerong Basin has been but small, the bulk has been drawn from the Lachlan Basin. The Shea's Creek Basin extends into a populous district, and the water derivable from it has for a long time been unfit for domestic use; it has never been utilised for the supply of the city.

The Botany sands are not barren, but are covered with a thick, low growth of vegetation commonly called scrub, and have therefore long been unaffected by the action of winds. The water storage capacity of clean drift sand has been illustrated by the Lachlan basin in a very conspicuous manner. From an area of 3740 acres sufficient water has been obtained for a constant service to about 200,000 persons. The average annual rainfall is about fifty inches, and for several years past very little water has been known to have wasted into the Bay. Population has closed in around the Lachlan basin, and the danger of pollution to the water is increasing. In a few months time the new water supply works will be so far advanced that the sand beds may be altogether abandoned.

The remaining feature to be noticed is the mud deposits. The most conspicuous of the mud deposits are found at the embouchure of Cook's River, and at the mouths of the various rivers and streams which discharge into Sydney Harbour, and its numerous ramifications. The head of each of the numerous shallow bays is generally found to be a shelving mud and sand deposits. A large area of these mud flats is exposed at low tide, and as the mud consists mainly of the debris washed from adjoining slopes, much unpleasantness is caused especially in the summer time. The total area of the mud deposits is about 2000 acres.

The clay shale beds which occupy so large an extent of the surface are known geologically as the Wianamatta Beds. They consist mainly of laminated clay shales more or less impregnated with iron in various combinations. The upper portion of the beds has been disintegrated chiefly by the action of the roots of plants and has been converted into clay varying in depth from two to six feet or more. This layer is more porous than the original compact shale, yet it is, in common with all clays, very retentive of moisture. The area occupied by the Wianamatta Beds is characterized by the undulating aspect presented along the flanks of the ridges—the undulations becoming flatter towards the main lines of drainage until they are almost lost in a general level. The slopes

on the hill sides are very regular and range about 1 in 20. This shows a uniformity in the texture of the shale which is not unexpected when its origin is considered. The clay and shale are easily and quickly eroded when exposed to the action of flowing water. Dense forests of large timber trees originally covered the whole shale formation.

The surface of the sandstone area is of a varied character, ranging from a compact level table to the extreme of ruggedness. Generally the surface is covered with a layer of angular boulders and sand, which has resulted from the weathering of the softer layers of rock and the disintegrating action of roots of trees. The sandstone rocks are traversed with vertical fissures which trend in two directions nearly at right angles with each other, and thus divide the rocks into large cubical masses. Rain water penetrating these fissures causes springs to appear at the base.

The natural healthiness of the site, taken as a whole, has been referred to as being a characteristic feature of the metropolitan district. A consideration of the nature of the various strata which form the surface will show their relative healthiness, it being generally understood that porous, open, well-drained soils are healthy, and that dense, undrained, or undrainable soils are the reverse. The sand stone areas and the upper portions of the sand beds, which rise into conspicuous hills, being well elevated, and naturally well drained, are the most favourably placed. The low-lying, saturated sands which receive the drainage water from higher levels take an inferior position. The area occupied by the clayey formation contains an insidious element of unhealthiness. The clayey soil and subsoil is very retentive of moisture, and its texture is such as to oppose that free drainage and æration of the ground which is so essential to the maintenance of an area in a habitable condition for man and other animals. This drawback is moderated or intensified in its action by the conformation of the surface. The summits of the hills and the upper portions of their sloping sides have the advantage of elevation to promote and facilitate drainage and the removal of subsoil water. The lower portions of the

slopes and the low-lying flat ground in the hollows or valleys are more or less charged, according to the season, with stagnant water. In winter these localities are very cold, and most certainly are very unhealthy; the fogs which form on the surface immediately after sunset are an indication of this. The natural condition of the mud flats is sufficiently indicated by their name, and needs no further comment. It will now be necessary to consider some of the effects produced by the advent of population on the areas just described.

The settlement of population in and around the metropolis has brought about many changes in the natural condition of the area, and the most important of these which directly affect its sanitary condition are as follows:—The removal of forest trees and shrubs, the pollution of the soils and streams, the deposit of silt and organic refuse around the outlets of the streams and watercourses, and upon the bed of the harbour, the accumulation of house refuse on the surface of the land, and the obstruction to the natural flow of surface and subsoil waters by the construction of road and railway embankments, infillings and reclamations.

Before proceeding further, it may be well to remark that nearly all of the most important works of modern sanitary engineering are provided on the general principle that pure water and pure air are the main elements essential to health. The degree to which the purity of the water supply has been affected by the changes just enumerated need not be investigated, for the necessity of providing an ample supply of water from a source outside the basins of the Parramatta and Cook's Rivers, long ago forced itself upon the attention of the authorities, with the result that a scheme was inaugurated, and is drawing nigh completion, which will accomplish the desired purpose. The town of Parramatta obtains its supply of water from the upper portion of the basin of the Parramatta River. This water is not of the best quality, and will rapidly deteriorate as population increases, so that resort to the new supply from the Nepean River must soon take place. It is, therefore, chiefly through the medium of the air that the evil effects of the aforementioned changes will be transmitted

to the residents, the principal exceptions being those which may be classed as dynamical.

The destruction of a large portion of the forests which once existed was necessary to afford room for the various purposes of civilization. This destruction still continues, and its effect is twofold—first, the purifying effect of the foliage upon the air is lost, and second, the shelter afforded to the soil by the foliage being removed, the soil when clayey becomes baked hard under the influence of the hot sun, and when rain falls it is not retarded, but flows quickly over the surface, and concentrating, rapidly erodes channels. The eroded material is carried by the flowing water and is deposited as silt at lower levels. Many water courses which are now deeply cut into the ground had no such defined position until the timber was removed from the surrounding hills. The removal of the forests has also had the effect of rendering the changes of temperature in the air more marked and sudden.

About one hundred years ago the first settlement of Europeans was effected upon the southern shore of Port Jackson, beside a small stream of fresh water which flowed into Sydney Cove. The water from this stream, which became known as the Tank Stream, was used for domestic purposes by the early inhabitants, but it was not long before the settlement, enlarging its borders, spread over the drainage basin of the stream and caused the pollution of its waters. A fresh source of supply had to be obtained. The stream soon became a receptacle for all descriptions of refuse, and as population grew denser it became a positive nuisance. Gradually it was hemmed in with buildings, and portions of its channel were covered over in various ways for various purposes—to increase yard space or to screen its offensiveness from view, and without regard to system. Whilst the stream was being transformed into a sewer the sandy mud flat at its outlet was gradually being raised with filling above sea level. A large area was thus reclaimed and appropriated to various purposes. The work of reclamation done at the outlet was not at once continued by the owners of low-lying land abutting on the stream higher up doing likewise; and these low-lying areas became liable to inundation during rainstorms,

owing to the stream being confined to a narrow channel through the reclamation. The fate of the Tank Stream has been the fate of other neighbouring and much larger streams. Although these streams have become almost obliterated as natural features, they make their presence known in a very inconvenient manner. The large closed channels which have been constructed to replace the original open watercourses prove in every instance too limited in capacity for the immense amount of water which rushes down from the adjacent slopes during heavy rainstorms, and in dry weather they become huge gas holders charged with the gas disengaged from the streams of decomposing sewage which meanders through the accumulation of silt on the floor. Outside the city boundary there are many other streams upon which population is converging; these seem destined to share a similar fate. Concurrent with the spread of population over the whole district comprised in the basins of Cook's and Parramatta Rivers and their tributaries, streets are being formed, water channels cut, and kerbing and guttering laid; these works, together with the hardening of the surface of the ground by traffic, cause the rapid concentration of the water resulting from rainstorms, which is then quickly precipitated into the main watercourses and channels. This concentration and rapid flow gives to the water erosive power, hence large quantities of silt, together with mud from streets and house refuse, are carried down and deposited around about the mouth of the stream, upon the flats, or spread over the flow of the harbour. Large accumulations of silt are thus being formed, a considerable proportion of which consists of putrescible organic matter. The decay of this matter, when exposed on the mud flats at low tide, is a growing nuisance, increasing with the increase of population. On some portions of the populated area, and, notably that within the city boundaries, the water carriage system for the disposal of fœcal matter and house slops has been adopted. At present the sewers discharge into the harbour waters, causing their pollution to an almost unbearable extent. A system of intercepting sewers, now in course of construction by the Government, will divert the bulk of the sewage, and cause its discharge into the ocean waters. Whilst the lighter

and most offensive matters will thus be removed, no appreciable diminution in the amount of heavy silt now discharged into the harbour will be effected. The solid and semi-solid refuse from dwelling houses and factories—that heterogeneous mixture known as rubbish—is got rid of in a variety of ways. When collected by the organised staffs of the city and suburban municipalities it is used for filling in excavations and natural depressions, for reclamations, and the formation of park lands, or it is deposited at recognized "tips." In the outlying thinly populated districts the householder throws his rubbish where most convenient. In this manner large accumulations of rubbish, containing a high percentage of putrescible organic matter, are gradually being made upon areas over which population is rapidly spreading, and even at this date many rubbish tips have become sites for dwelling houses. In and around the metropolis the original topographical features have been greatly changed by the grading of streets, preparation of building sites, formation of railway embankments, and reclamations. Little thought appears to have been given to the effect which such changes may have upon the surface and subsoil drainage. Original watercourses and depressions have thus been in many instances entirely obliterated, and subterranean basins formed by the embankments made across the natural lines of drainage. Whatever water percolates through the surface finds, in many cases, a permanent lodgment beneath. It is well known that this subsoil water, after acting as a leeching agent of a stratum, consisting largely of organic refuse, is scarcely less foul than sewage itself. Above these subterranean accumulations of foul water the ground air brings to the surface those poisonous emanations which are invariably the result of the putrid decomposition of animal matter. Of all the dangers to health which may surround human habitations there is none which more insidiously undermines health than a saturated surface or subsoil. Any level undrained surface is unhealthy, but the concentration of unsanitary influences arising from want of drainage is apt to be found where the surface or subsoil receives the fermentable refuse of a crowded population.

The previous remarks upon the natural condition of the whole area, and the unhealthy results arising from the settlement of population thereon, lead now to the considerations of what should be done to improve its present sanitary condition, and provide beforehand for future requirements.

Mr. W. Clark, in his report to the Government on the drainage of the city of Sydney and its suburbs, has indicated the steps which should be taken in regard to low-lying areas bordering the harbour. Referring to the low land at Double Bay, Rushcutter's Bay, and Lacrozia Valley, he says: "In all these places, where the land is but a few feet above sea level, and too low to afford healthy sites for houses without pumping the drainage and subsoil water, I would recommend that the further erection of buildings should cease, that the land be resumed by the Government, and laid out for public use as places of recreation; moreover, that in each of these cases an open channel be formed through them for carrying off the surface waters of the district, which has here its natural outlet." Mr. Clark's recommendation should be carried out in its entirety, and ample scope will be found for its application to those extensive low-lying areas at the outlet of Cook's River and those marshy unhealthy areas so frequently met with bordering the harbour, particularly westward of the city.

It has been the practice hitherto, when making reclamations, not to continue the filling in landwards beyond the high water mark, which frequently is the boundary of private property. This practice must not continue; the level of the surface of the reclamation should be continued inland, with a gentle rise until it meets the natural surface, otherwise great evils will arise, an unfortunate example of which is exhibited by the Blackwattle Swamp reclamation. The open channel should be so capacious that the level of the flood-waters will not be unduly raised in their natural inland channels, and so cause damage to private property. In some instances canals may easily be constructed, which will afford ample escape for storm-water, as well as giving facilities for trade. At Iron Cove Creek, Long Cove Creek, and Hen and Chicken Bay canals could easily be cut as far as the main western road. These

canals would not be expensive to make, and would be a considerable step towards the reclamation of the large tracts of swampy land which exist there. No matter what improvements may be effected a large amount of silt will be carried down by storm-waters. If the reclamations around the outlets of the main drainage channels are improperly made the silt will be driven further out into the harbour and spread over the bottom. If steps be taken to encourage the deposit to accumulate in one place its removal by means of dredges will be facilitated.

A radical change is necessary in the method of treating the main lines of natural drainage along the bottoms of the valleys. Instead of allowing population to hem the creeks and watercourses in, and confine them within the narrowest possible bounds, which is now the practice, a reserve should be made not less than two chains in width all along the bottom of the valley, so as to include the watercourses within its limits. The irregularities of the channel would have to be corrected by straighting the course and carrying it along the centre of the reservation. The whole of the bottom of the channel and the sides for a portion of their height would have to be concreted or bricked. A roadway aside of the channel would be required for effecting the removal of silt and rubbish. Plantations of trees at a sufficient distance from the channel to prevent drainage from the roots could be made and outside the plantations streets for ordinary traffic. Under no circumstances, whatever, should the channel be covered over, but it should be left to the full influence of the purifying action of the air and sunlight. A channel so constructed would be essentially a storm water channel. For the conveyance of sewage, small sewers would have to be constructed one on each side.

The channel would afford a convenient outlet for subsoil drains, which are absolutely necessary for rendering healthy extensive, flat, low-lying areas chiefly in the western suburbs.

Subsoil drainage does not appear to have received much attention yet, and there are many areas which would be all the better for the institution of this highly desirable sanitary measure. The writer has been observing the effect of the recent prevalence

of wet weather upon the clayey soils of the western suburbs, a good opportunity being afforded by the numerous trenches opened in connection with the laying of water pipes, and there is but one conclusion to be arrived at, which is, that a sewerage scheme for those districts unaccompanied with systematic subsoil drainage, and the prohibition of residence on low-lying areas will not secure those results which it is expected to accomplish. Sub-drainage should be provided in all cases where the construction of road or railway embankments may tend to cause the accumulation of subsoil water on the uphill side. The great weight of the superincumbent bank of earth compresses the underlying soil, and thus obstructs the passage of the water. The mass of earth in the embankment being loose acts as a sponge rapidly absorbing the rain which falls upon it, and gradually discharging it at the base. The ground on the lower side of the embankment will thus be kept damp and unhealthy, as well as the upper side. The extensive filling in at the site of the Railway Workshops at Eveleigh, may be expected to cause an unhealthy dampness in the ground on the downhill side. This area being flat, clay ground always was damp and unhealthy, its condition must now be worse. Unfortunately it is being rapidly covered with dwelling houses. There are numerous other instances of a similar character and the evils now arising from them could have been largely, if not wholly, prevented by a proper system of subsoil drainage. No doubt, in the near future many railways will be constructed in the Metropolitan district, and precautions against retarding the subsoil drainage should be taken. All filled in areas should be drained. Drainage will not correct all the evils which result from the use of house and street rubbish for filling in and levelling up purposes. The application of town rubbish to such purposes should be absolutely prohibited. Healthy sites for dwelling houses can never be formed with such materials, even if a layer of so called sound rubbish is spread above it. An evolution of poisonous gas will be coincident with every fall of the barometer. A proportion of this gas will rise under the floors of houses built over the area and find its way into the rooms above. In the summer time sudden

changes in the barometric pressure of the air are frequent, and are of common occurence after sunset. The warmth of the season accelerates the decomposition of the organic matters in the mass of filling causing the disengagement of large quantities of gas which, if the change in the air pressure takes place during sleeping hours, must lower the vitality of those subjected to its influence. The impervious covering formed by the concrete foundations of wood paved streets will compel the ground air to seek outlets at the sides in dangerous proximity to cellars and basements. It is not clear how this evil may be avoided. All house and street refuse should be destroyed by fire. In growing communities rubbish tips cannot be kept out of the way of advancing population. The thorough and systematic cleansing of the surface of the populated areas is necessary to reduce the pollution of the harbour and rivers. The conveyance of liquid refuse from dwellings all over the Metropolitan area will no doubt be eventually effected by sewers which will receive the fœcal refuse as well. The disposal of the sewage is a problem, the solution of which will present many difficulties. A scheme for the interception of the sewage, which at present flows into the harbour from the city of Sydney and several adjoining suburbs, and its conveyance underground to the ocean, is nearly completed. The districts remote from the coast line are debarred from using a similar method. Two other courses are, however, available. The sewage from each separate valley may at its outfall into the harbour be filtered. Where the discharge would be effected into the salt water the refined degree of purification necessary in those instances where the discharge takes place into fresh water streams would not be required. At the bottom of all the valleys reclamations are necessary and these reclamations if made would form convenient sites for filter beds. Under such a scheme each valley should be made a district, the residents of which should be held responsible for the proper disposal of all their solid and liquid refuse—they should have the use of reclaimed areas for recreation purposes The cost of the necessary works and their maintenance would be defrayed by a rate levied within the district.

The other course open is to collect the sewage at the various outfalls and pump it to such an elevation as may be necessary, to enable it to descend by gravitation to the coast, or on to an area of ground inland prepared for use as a sewage farm. In deciding upon the adoption of sewage schemes for the inland districts it will be necessary to provide for a very large population. Sewage schemes when carried out afford such a convenient means for disposing of much unpleasant matter, that it is possible to crowd a greater number of houses upon a given area than would otherwise have been possible. Dr. G. V. Poore refers to this in a lecture delivered by him recently in London. He said: "A complete system of water-carried sewage encourages overcrowding, because a sewer does away with the necessity of any curtilage to a house The density of population in some parts of London steadily increases. What once were gardens or back yards are now dwelling houses. Houses steadily increase in height, and, there being no need of any arrangement for filth disposal, except by a sewer, the houses are built in seried ranks, and often back to back. We make no serious efforts to control building schemes, but when with the lapse of time, the dwellings of the rich become the dwellings of the poor, we simply wonder what is to be done, and make no effort to prevent what we are almost powerless to remedy. From a sanitary point of view overcrowding is most undesirable. It breeds squalor, discontent, and disease."

Dr. Poore's remarks are essentially true, and show the necessity of legislative action being taken to limit the number of houses which shall be allowed on a given area of land. Such action would be a most desirable adjunct to Mr. Reid's Widths of Streets and Lanes Act. It should also take cognisance of those areas which are, by reason of their low elevation, utterly unfit for habitation.

The density of population on any area has a direct influence upon the rapidity with which rainwater, falling on the uplands, will be precipitated on to the lower levels. The volume of water which flows off an unbuilt-on area during a heavy rainstorm is no indication of the amount which will flow off during a similar rainstorm when the area has been extensively built over. The tendency is

always to diminish the time required, on account of the facilities afforded by paved channels and drains for the rapid down flow of the water. Amply capacious storm-water outlets should, therefore, be provided for all districts which in the near future will be thickly populated. These storm-water outlets should be quite distinct from the sewers, for they serve a different purpose.

In concluding these remarks the writer desires to draw attention to the necessity that exists for legislative action and the passing of laws for the promotion, as well as the enforcement, of sanitary measures, without which many existing evils cannot be successfully combatted, nor can measures providing for future requirements be undertaken. And another important consideration presents itself — it is this: The people generally require educating on sanitary matters, and their knowledge of the laws which govern health increased. With this education of the masses attained, proper sanitary enactments will achieve the best results.

9th JUNE, 1887.

W. D. CRUICKSHANK, PRESIDENT, in the Chair.

THE following Paper was read by Mr H. W. Kerle :—

OCEAN JETTY.

For the North Illawarra Coal Mining Company, North Bulli.

BY H. W. KERLE.

THIS is the latest of a number of jetties constructed on the coast, for the purpose of loading coal from the various mines situated on the seaboard of New South Wales. It may not be here amiss to state, briefly, the various works of this class that have been erected up to this time. The first was at Bellamby, between Bulli and Wollongong, over thirty years since ; it was of a very temporary character, and, owing to the great difficulty of getting alongside with a sailing vessel, it fell into disuse, and eventually, through decay and damage by storms, it washed away. Precisely the same fate overtook a similar jetty constructed about the same time at Catherine Hill Bay. Only about 120 feet of this is now standing (or falling), but there is one point of interest in it which the author considers worthy of notice. On examining the piles he found that they principally consisted of ti-tree, and were in apparently a sound condition ; they did not seem to be affected in any way by the cobra or other sea worm ; this state of preservation, after a period of immersion of fully thirty years, appears to him remarkable; but the rock formation being a conglomorate highly charged with iron pyrites, may to a great extent account for it.

Next in order come the Bulli, Coal Cliff, and Kembla jetties ; these have now been in use for some years, that at Bulli being a well known landmark familiar to many travelling by sea.

The work forming the subject of this paper was commenced in April, 1886 ; it has been in use since January of this year, and is now on the point of completion.

It begins at the junction of the lines of railway from Nos. 1 and 2 mine, and is carried out across a small indent in the coast, known as Hick's Bay (Plate 5), in an easterly direction, being partially sheltered from the effect of a southerly gale by a headland and a low lying reef of rocks, but exposed to all weather from the S.E., E., and N.E.

The bottom consists of a shale rock, generally soft and easy to work, but having patches of a hard nature. Overlying the rock is a shifting bed of sand, which varies greatly according to the state of the weather; this has caused considerable obstruction in the carrying out of the work.

From the commencement outwards, about 250 feet, the reef falls very gradually, being immersed at high tide. From this point it drops quickly into deep water through broken rocks and boulders, and falls gradually outwards.

The general dimensions are:—Total length, 870 feet; width, 30 feet from the outer end to 620 feet inshore, thence 42 feet to 180 feet inwards, from which it branches off in two wings to Nos. 1 and 2 mine, at a width of 23 feet each; height from reef to deck at inshore end, 30 feet, and at outer end, 56 feet. Depth of water varies from 22 to 25 feet, according to the state of the sand.

The construction of the work is shewn in elevation and plan, plate No. 6, and in sections, plate No. 7. The deck load it is designed to carry is that equal to a 12-ton locomotive and train on the double line. The piers of the wings carrying the superstructure are formed in the manner shewn in the section AA. The piles are not less than 15 inches diameter at the smaller end, and 20 inches at the butt, the larger end being placed downwards. The butt is adzed round a distance of 2 feet 6 inches and to 18 inches diameter, on which two wrought-iron rings, 4 inches x 1 inch, are shrunk on, one at the upper end, the other close to the base. In the centre of the pile a hole is bored to receive a dowell-pin, 3 inches diameter.

At the head the piles are tenoned into an ironbark headstock, 14 inches x 14 inches, and secured each with double anchor bolts. The centre pile is vertical, and the other piles have each a batter

of 1 in 5. They are braced with double whalings, notched into and bolted to the piles; the diagonal bracing being 9 inches x 5 inches, toed into the whalings and bolted to piles and headstocks respectively. At the junction of the two wings, and for the next eight bays, the piers are constructed with four piles, these are the same size as those before mentioned, and are finished at head and butt in a similar manner. They are braced as shewn in section CC, above H.W.M., with 12 inches x 6 inches double whalings, and 9 inches x 5 inches braces, notched in and bolted. At the termination of the four pile work, which completes the widening out of the deck for the purpose of sidings, crossings, &c., the piers are constructed for a further distance of 180 feet in the manner shewn in section BB. The whole of the work in this portion is similar to that previously described, with the exception of the chain bracing below water, which is substituted for wood to avoid the strain which would inevitably occur by the action of the waves upon it, and thereby be a source of weakness instead of strength. These chains, which are $\frac{3}{4}$ inch diameter, are secured to the butt of each outside pile by means of a heavy bolt passing through them, the head being forged into an eye to which the shackle of the chain is fixed. Immediately under the longitudinal whalings similar bolts are fitted, to these a shackle and bolt are fitted, which work into a hoop secured to the end of the chain. They are thus, after fitting, all hauled up taut and made fast at their intersection with the centre pile by a suitable staple. Up to this point, or 420 feet from shore, the piers are set 20 feet apart, and from hence they are spaced 15 feet apart, and are constructed in the manner shewn in section CC, to within 30 feet of the termination of the jetty. As will be seen the work here throughout is of a similar character to that previously described. The two outer piers are constructed in cast-iron columns, there being two to each pier. They are cast in sections 5 feet 6 inches long, 3 feet internal diameter, thickness of metal 1 inch, flanges $1\frac{3}{8}$ inch. Each section is cast with spigot and faucet, which are accurately turned to fit and made interchangeable. Internal flanges, $1\frac{3}{8}$ inch thick, are provided to secure one to the other, the

bolts being $1\frac{1}{8}$ inch, $4\frac{1}{2}$ inch pitch. In the positions shewn on elevation DD, there are cast pockets for the purpose of receiving and securing the ends of the struts, which are formed of 12 inches x 6 inches rolled girders. These struts are made fast with one pin in each end, 2 inches diameter, passing through the sides of the pocket and webb respectively. The top sections are formed in a similar manner generally to the others, but there are intermediate flanges 16 inches below the level, and the sides of the cylinders are cut down to allow the girders forming the struts and carrying the deck to finish flush with the cap. The transverse girders, viz., those carrying the longitudinal wooden girders to which the deck is spiked, are built; they are 16 inches deep, 12 inches wide, and of the length shewn in section; they run across the whole width of the cylinder, and are thoroughly bolted to the flanges before mentioned. The longitudinal girders are rolled joists 15 inches x 6 inches, with cover-plates top and bottom, 9 inches wide x $\frac{1}{2}$ inch thick; they rest on and are secured to the flange at head, and are butted and strapped to the transverse girders. Below these girders, in the position shewn, are two diagonal struts of 12 inches x 6 inches rolled iron, the ends of which are received into and secured to pockets cast on the sections in a manner similar to those below. On both sides and ends the columns are braced vertically as shewn, the tie-rods being 2 inches diameter in the body. The end of each rod is hooped to pin passing through pocket, the other being screwed up taut to ring in the centre. These cylinders are filled with blue metal concrete to the top for the purpose of giving additional strength and weight, and to prevent the corrosion on the inside which would otherwise more quickly occur.

From the inner columns, and extending to the commencement of the wings, a thorough system of horizontal bracing has been introduced, for the purpose of distributing the strain on the piles at this, their weakest, point, and to knit the whole together. For this purpose, beneath the horizontal cross whalings and at 8 feet above high water, longitudinal whalings have been run through to the point shewn on Elevation Plate. These are scarfed and bolted on

the piles, and fitted with chock underneath. Notched into these, and secured to intermediate piles, are double horizontal diagonal braces of 9 inches x 5 inches, as shewn on body plan, Plate 6. The whole of this work is scarfed, bolted, and knocked-in in an exceptionally strong manner.

On the top of the headstocks, and forming the lower portion of the superstructure, and under the girders are corbels of ironbark 14 x 12, and 14 x 9, respectively, those on the piers spaced 20 feet apart, being 8 feet long, whilst those on the 15 feet bays are 6 feet; they are all notched into and bolted to the headstocks. The deck is carried by four ironbark girders, 14 x 12, and two of the same material 14 x 9, at the sides. The large girders are placed immediately under the rails, to take the strain of the traffic direct; they are bolted and butted to the corbels. The deck is 9 x 3, hardwood, laid slightly open, and secured to the girders with 8-inch x $\frac{1}{2}$-inch spikes. The kerb is 9 inches x 6 inches, scarfed off for 2 inches on the inner edge, and bolted to girder. The rails are laid on continuous sleepers of 12 x 6 hardwood, which is bolted to the girders.

There are three sets of fender piles constructed, as shewn on section CC. Each set is formed of three vertical piles, pinned into the rock in a similar manner to the bearing piles, and having two diagonal strut piles toed into the rock, and secured with vertical dowel. The head is secured to cross strut, which is notched into the uprights.

These fenders are distinct, and clear of the jetty in every way, and, in the event of their being carried away by the roll of a vessel upon them, no damage or strain would result to the main portion of the work.

In the position shewn on Plate, 400 feet from the outer end of the jetty, a landing stage and steps are erected. The stage is constructed about 9 feet above high water mark, and is carried up by means of an extention of the horizontal cross whalings. It is 20 feet long, 4 feet wide, and formed of 6 x 4 hardwood, laid on edge, there being a space of 4 inches between each piece, and they are each secured by through bolts at each end. Leading

from low water mark to the stage is a wrought-iron landing stairs, the top end being hinged on to the stage, the bottom being swung with a substantial chain. From the stage to the deck a substantial set of steps is fitted: it is constructed of 12 x 4 stringers and 9 x 3 treads. A neat handrail of wrought-iron standards and wire rope encloses the outer side.

Sixty feet from the end of the jetty the apparatus for loading is erected. The trucks in use all open with bottom doors. Between the rails on the up line at this point a hatchway is cut, which communicates with the shoot below. The shoot is formed in two pieces, the upper portion being fitted round and enclosing the hatchway, and secured to the girders with strong angle-iron, the lower end being carried up by straps secured to the outer girders. The lower portion of the shoot is movable; when not in use it rests upon a staging constructed for the purpose, with two piers of two piles each, having headstocks, girders, and planking similar to that used in the jetty. This staging is 10 feet below the level of the deck. On the bottom sides of this shoot are fixed four wheels, and at the back of the stage a small winch is provided to run it in and out. Erected on and above the kerb is a substantial jibbet constructed of 9-inch x 9-inch posts, and well stayed back on to the main girders with 2-inch x 2-inch square wrought-iron rods. In the centre of the jibbet a set of 3 x 2 blocks are fixed, and on the deck a double powered winch is fitted.

When in use the shoot is lowered and held in position by the fall of the rope from the blocks overhead round winch barrel, and the small winch tackle on the lower stage; whilst in case of danger, or when not required, it is hauled up to the large winch and run home by the smaller on to the stage. It is thus completely under control, may be held in any position required, or lifted clear of danger in a very short time. The moorings in use are situated on the port, starboard-quarter and stern of the jetty, as shewn in the local sketch, Plate 3. The first three are held in position by large anchors dropped into the best available holding ground. Each buoy is connected to the anchor stocks with 125 fathom of stud cable $1\frac{1}{8}$-inch diameter. The stern mooring is pinned to the solid

rock on the shore. From these moorings the vessel, when loading, rides, and does not at any time touch the jetty, and, if properly handled, but seldom the fender piles.

The Company, having a large amount of timber on the estate, together with an efficient saw mill and workshop adjacent to the jetty, considered it advisable to undertake the work and risks incidental thereto themselves, under the management and charge of a resident engineer, rather than let it by contract. The whole of the timber for decking, braces and whalings was obtained from the estate, and sawn as required. The girders and headstocks being of ironbark, and, as this was not obtainable in the district, it had to be brought from the Manning River and landed at Wollongong, and hauled to the site. The piles, being of turpentine, were obtained on the property. The large amount of timber required entailed much hard work in its selection to maintain its quality.

Before commencing the erection, a suitable crane, running on wheels and having a jib 28 feet long, was constructed, which was made movable horizontally but was otherwise fixed.

The first portion of the work for 250 feet was comparatively easy to erect, the rock being generally uncovered at low water. After the curves of the wings were struck, the positions of the piles in the piers were marked off, and the holes for the dowels on the ends of the piles were drilled with augur and drill in the usual way to the required depth. The rock on which the butt of the piles rested on was then dressed off and the pin driven home. The piles forming the first pier were then each lifted on to the pins, the heads cut off, and headstock, corbels, and girders fitted and permanently fixed, the deck being laid loosely. The crane was then run out, and lifted the next pier into position together with the other necessary timbers; in this way the work proceeded to its completion. Immediately each pier was erected, it was treated in this manner, the other portions, viz., braces, whalings, &c., being brought forward at the same time, or as soon after as possible, and completed. Very little temporary work was used or required, and the liability of damage by sudden storm was reduced to a minimum. In fact, the whole of this work was completed without a single stick

being washed away; and this in the face of some of the heaviest weather that has been known on the coast for years, and especially of the storm in November, 1886, which was quoted at the time as the worst experienced for the last 40 years, when the jetty was at that time advanced to 700 feet from shore. Careful management and foresight, a constant stock of the required material, together with an efficient staff of first-rate men was absolutely necessary for the carrying out of the work in this manner. Beyond low water outwards considerable difficulty was experienced—in the first place owing to the wash and boulders, and latterly in the accumulation of sand, which had to be removed before boring the holes for the dowels and to clean off the surface of the rock for the seat of the piles. The boulders were broken up by blasting and removed. Movable boxes were constructed encircling the pile to be erected; the divers then removed the sand and held the drill in position while the hole was being pierced from on deck. The pin was then inserted in the hole and the pile driven on to it, any sand being removed from underneath. The centre of each pier was taken from the centre of the jetty; temporary girders were run out for the purpose of lowering a staging for drilling the holes from the upper whalings, and the exact depth being found, the hole was marked off from above and driven with the requisite batter to suit the pile. As each pile was erected, it was fitted with a temporary brace until the whole number forming the pier were up, when the heads were cut off and the headstocks put on, &c.

The work of erecting the cast-iron cylinders has been of a laborious character. The base of each column has been sunk into the rock a distance of five feet. Sinking these holes in the exposed position has been a difficult undertaking, more especially so as the weather during the whole of the time (some four months) has been most unsettled, considerably more than half of the time it being impossible for the divers to work, and frequently, no sooner had the debris been removed from the hole being sunk and the work recommenced, than they were again compelled to stop. The method of sinking consisted in drilling a number of holes 3in. diameter round the circumference

of the hole, which was slightly larger than the required size; after these holes were completed, one was in a similar manner put down about the centre, into which a dynamite charge was inserted and fired by a battery from on deck. This had the effect of loosening the core, after which it was removed, the sides being cleaned off and the bottom dressed perfectly level. On the four holes being completed the bottom sections were lowered and secured into position with concrete. The levels of each section were then taken, and the matching pieces ordered so as to bring the intermediate struts and cylinders horizontal and level on completion. An unavoidable delay occurred during the time these final sections were being cast and turned, during which time (three weeks) beautiful weather prevailed, but when forthcoming nothing could be done towards fixing them for another ten days on account of heavy weather. As soon as practicable, the remaining sections were lowered and bolted up securely up to the first set of horizontal struts; matching pieces were then lowered, the holes marked in the flanges, taken up again, bored, replaced, and the struts and braces fixed in position. The next sections were then lowered up to the second set of struts and braces, when the work had to be discontinued owing again to bad weather. The author hoped, on commencing this paper, to have been able to say that the whole of the work was completed, and without accident of any kind, and such would undoubtedly have been the case had the weather held favourable for another four days, but, unfortunately, when within sight and confidential expectation of a satisfactory ending, an unforseen and somewhat serious accident happened.

On Thursday 2nd inst, a strong wind and heavy sea sprang up, causing work to be discontinued. This was at a period when the two outer cylinders were about thirty-five feet high, the inner cylinders being up to the second strut, or forty feet high. Before stopping the work everything was secured, so far as the unfinished nature of the work would permit; the whole of the cylinders being completed, as shown on elevation DD, and they were temporarily braced back on to the jetty. During the night the sea increased

to a gale, and coming from the N.E., it, as may be seen on the local sketch, struck the jetty in the worst possible position. The quarter buoy having snapped the mooring chain, broke loose and rode on the hawser (twelve-inch), one end of which was fixed to the northern side of the jetty; it then washed into the bay, outside the outer cylinders, carrying the hawser with it, and owing to the strain thus induced by the buoy being driven by the sea, it acted as a lever of about six to one on the top sections of the cylinders, and by also taking them in a diagonal direction to the jetty it literally dragged them over. The flanges in the bottom sections were ripped out, and both cylinders fell, breaking off the shoes holding the struts in position. The inner cylinders owing to their being stayed back on to the jetty remained secure. Had the cylinders been coupled, or had even the second set of struts been fixed, the accident could not have occured, as the whole would have been secured and braced on to the jetty, and the action of the rope on the buoy would have been reduced to a minium, as the strain would have been that of a simple pull, and the point taken above the portion acted upon instead of at the fulcrum on the flange at the rock. The author does not under-estimate the force of the sea itself acting on the cylinders independently of the above cause, but he feels confident that the force of the water acting on the round surface of the cylinders was not nearly sufficient to have caused the damage of itself, although he has no doubt, that it materialy assisted in the result. Whether it was one, or both that caused the accident, it undoubtedly occured during the most critical period of the work, and was such that it was impossible to calculate on, or provide for. When these cylinders are erected and completed with the girders secured in position at the head, and the horizontal and diagonal struts, and vertical diagonal braces in position, they will form a hollow column or pier, having a base to be acted upon of thirty-four feet by thirty-four feet, and the author thinks that there is no sea capable of acting upon it with sufficient force to overturn or destroy it, whatever may have occured lately, and also that they will, as designed, greatly add to the strength and stability of the whole structure, by providing a tie

to the jetty at the outer end far stronger than it is possible to obtain by piles or any other means.

On referring to the local sketch it will be seen that the jetty is very greatly exposed, in fact, far more so than any other on the coast. It is protected partially from the south by the headland and by the low long reef; this latter is sufficient to break the full force of the water, yet a large amount is felt, and the breakers over it are very heavy during a gale. From the S.E. to the N.E. it is completely exposed and receives the full force of the sea. The gales which occurred whilst it has been in construction have been numerous and heavy, the waves have risen some feet over the horizontal whalings, and on one occasion the spray reached the deck. During these trying times the works resisted he strains put upon them remarkably well; a sea could be felt striking the end of the jetty, and the strain transmitted through the whole structure to the shore, thus proving the immense value of the longitudinal whalings and diagonal bracing. In designing this work great care was taken not to expose more material to the action of the sea than was absolutely necessary for its safety and durability, it being thoroughly recognised that in this instance an excess of strength (apparent) was virtually an element of weakness; nothing, therefore, has been done more than has been considered absolutely essential to carry out the above object, and what has been done has been completed in the strongest and best possible manner; whether the best means have been adopted to secure the desired end remains to be further proved by the best judge, viz., time. The cost of the work when completed will probably not exceed £12,000. This work has been designed and carried out by the author in conjunction with his brother, Mr. Walter Kerle, who has been, and is, the resident engineer, and who has had the direct charge and management of the whole, great praise being undoubtedly due to him for the manner in which it has been pushed on, and so near completed. Mr. James Coulter has acted during the whole time as foreman of works in a thoroughly efficient manner.

14TH JULY, 1887.

W. D. CRUICKSHANK, PRESIDENT, in the chair.

THE following candidates were balloted for and duly elected as

MEMBER:

ANDREW CHRISTIE.

STUDENTS:

P. T. OWEN.

A. T. HINDE.

E. W. FINCH.

The President informed the members present, that this meeting was the last to be held in the present rooms in Bank Chambers.

Mr. W. G. Wilson then read a short sketch on the progress of steam navigation during the last thirty years, and referred to the intimate connection with some of the most interesting features in connection therewith, which, Mr. John Fife, the Association's first president, experienced, who was present as guest.

11th AUGUST.

W. D. CRUICKSHANK, PRESIDENT, in the chair.

The following candidate was balloted for and duly elected as

MEMBER :

Dr. JOHN STORER.

The President welcomed the large number of members present to the new rooms in No 5 O'Connel Street, and thought the Association might be congratulated upon having secured most suitable premises at a moderate rental. Mr Norman Selfe then read the following paper:—

ON RAILWAY BRAKES.

BY NORMAN SELFE, M.I.C.E., M.I.M.E., &c.

THIS paper is not intended to be anything like so exhaustive as that on "Compressed Air and its Applications," which the author had the honor of presenting to the last session of The Association.

For the purpose now in view, it is unnecessary, to investigate the scientific principles involved in the action of railway brakes, as they all centre in one object, and that is, to get rid of the accumulated energy as soon as possible. In practice, this is accomplished by converting the energy into heat, and dissipating it to the atmosphere through the medium of the brake blocks by their pressure on the tyres of the wheels, which, of course means a most wasteful operation.

It must be borne in mind that the quantity of work stored in a moving train is equal to the weight of that train multiplied by the height a body would have to fall by gravity to acquire the same velocity; and thus, by the laws of gravity, a given weight at 20 miles an hour has not twice, but four times the work stored in it than it has at ten miles an hour, and at forty miles an hour it has sixteen times instead of four times the work in it.

In round numbers it may be said that for each ton of weight in a moving train the accumulated energy is as follows :—

at 60 miles an hour	-	-	-	120 foot tons.		
40	,,	,,	-	-	-	53 ,, ,,
20	,,	,,	-	-	-	13 ,, ,,
10	,,	,,	-	-	-	$3\frac{1}{4}$,, ,,

so that a train of the moderate weight of 200 tons only, at sixty miles an hour, has about 24,000 foot tons of work stored up in it, or, in round numbers, what is equivalent to 1600 horse power for one minute, or 160 horse power for ten minutes ; this makes it evident what an enormous waste of power takes place in train stoppages, when made at high velocities, and explains the production of the fragments which result from a sudden stoppage or collision.

Although many schemes have been tried, on a small scale, to store up some of the power lost in stoppages, by means of springs or compressed air, which could be used to assist in starting again, there is only one practical way in actual use on railways, and that is to throw it away in heat, generated between the wheels and the brake-blocks. This paper will, therefore, only deal with the mechanism used for moving the blocks on and off the wheels.

At speeds of, say, 10 miles an hour, the friction of railway wheels skidding on dry rails is about one-fifth of the weight, and when very dry one-fourth.

The friction reduces as the speed increases, and as the rails are lubricated by moisture. From experiments made on the District Railway in London, at a speed of twenty miles an hour on damp rails, the co-efficient of friction was reduced to one-ninth.

If a train could only be stopped by arresting the revolution of the wheels and allowing the tyres to skid on the rails, the co-efficient of friction and the velocity would give us the distance in which it would come to rest; but the result would soon be to make polygons out of the wheels instead of circles, from the flats that would be worn on the tyres. It is, however, found in actual practice, that the retarding power of brakes is greatest when the wheel revolves with a friction on the brake blocks just less than

that which would cause the wheels to skid. In a memorable series of experiments conducted by Captain Galton in 1878, the advantage of non-skidding as against skidding the wheels was conclusively proved, and many points which were up to that time matters of opinion only, were set at rest by actual trials.

It is now settled that the best method of braking a train is to apply blocks to the peripheries of the wheels. It will be thus seen that, to stop a train as soon as possible, it is necessary to retard, or arrest all the wheels in the train, with as much pressure as possible short of stopping them, and that this possible pressure is variable, increasing with the velocity. What has to be considered now is the working of certain contrivances which will bring the brake-blocks into contact as forcibly as required, and as surely as possible, and remove them when no further required, viewed from the standpoint of the practical engineer accustomed to the use and keeping in order of machinery.

When railways were first introduced, it was quite sufficient to apply brake power to the engine or tender by means of a screw and levers, and then to the guard's van; but as the system developed, with increased weight of trains and higher speeds, the necessity of more brake power became manifest; and in England the special attention of the railway companies was called to the matter by the Board of Trade in 1858.

It would be quite impossible this evening to give a history of the Battle of the Brakes, or even to describe all the leading inventions that have had a trial in actual practice, if it was desirable to do so, but reference will be made to the four leading classes of brakes which have been introduced during the last twenty years, and the most prominent ones only be more fully described.

First, Chain Brakes. It is easily understood that a winding drum can be affixed to the engine, the tender, or the guard's van in such a way that it will wind up a chain when a clutch or friction wheel brings it into connection with a revolving axle, and that this chain can be passed around sheaves attached to levers under each carriage from end to end of the train, so that the effect of winding it in from either one

end or the other will be to force the brake-blocks against the wheels. Some years ago, before the author knew anything of Wilkin and Clarke's, or Clarke and Webb's chain brakes, he worked out a brake, in conjunction with a gentleman in the New South Wales Railway Department, and after it was brought to what was then thought a pretty perfect condition, it was found to be almost identical with Clarke and Webb's brake, as used formerly on the London and North-Western, and tested at the Newark trials, in 1875. Since then the author has paid no attention to chain brakes, although there are several varieties that have had their day, but they appear to be fast becoming things of the past.

Secondly, Hydraulic Brakes. A number of hydraulic brakes have been invented, tried, and successfully worked. In Australia they have been brought under notice from the fact of the Hon. Mr. Woods, of Melbourne, having a patent which has had an extended trial on the Victorian railways, but the title is somewhat misleading, as the water used is only the connecting link, and compressed air actually stores and gives out the power to set the brakes.

In the Wood's brake a cylinder and piston is fitted to the vehicle for putting on the brake, and water is pumped from the engine through a train-pipe and special valve into an accumulator, where the air is compressed by the water and becomes a spring. On the release of the pressure in the train-pipe the regulating valve allows the water to pass from the accumulator into the brake cylinders, and set the brakes with the pressure of the compressed air. On the restoration of pressure, when a further supply of water is pumped into the pipe, it refills the accumulator, and at the same time alters the valve and lets the water escape from the brake cylinder so that the brakes come off. The author knows nothing of the actual results in efficacy and cost of the Wood's brake; but as the comparitive friction of air and water is as the weights of the two mediums, it seems to him to be impossible that a water medium can ever be made to operate so quickly as air. Its want of elasticity is also against it. There are other hydraulic brakes such as Barker's, but as instantaneous and simultaneous action on all the

vehicles are important points of a modern brake, the hydraulic system will be no further referred to.

The principal battle now taking place in railway brakes is between rival systems all using air, but divided into two broad classes—viz., those working with pressure much above the atmosphere, and those working with less than the atmosphere, or vacuum brakes. The best known vacuum brakes at the present time are, the author believes, the Smith or Adams brake, very largely used in England on the London and South-Western, and over thirty other companies in one form or another, and which brake was shown in actual work at the association's exhibition in Prince Alfred Park; the Eames vacuum brake and the Westinghouse vacuum, which last seems to be practically abandoned, as it is not heard of now. The former two brakes—the Eames and the Adams—both operate by the pressure of the atmosphere on a piston or diaphragm when there is a vacuum or partial vacuum on the other side.

The principal pressure or plenum brakes, operated by air pressure above that of the atmosphere, are, perhaps:

The Westinghouse Non-automatic, as formerly used on the New South Wales lines.

The Westinghouse Automatic, now in use in New South Wales.

The Carpenter Automatic.

The Hanscom Automatic.

These automatic brakes are also made as electro air brakes, the two first of them having been fitted with electro pneumatic attachments for instantaneous application, and tested in May last near Burlington, Iowa, U.S.A.

The Westinghouse non-automatic brake was working in America in 1869, and on the Caledonian Railway in 1872. A very full description is given in "Engineering," vol. xiii. It then had a duplex train pipe, for simplicity of coupling up, and for providing extra security. This non-automatic brake is going out of use, although it is, in some respects much safer for mountain lines than the automatic brake, and for reasons well set forth in a recent number of the Journal of the Society of Arts.

Vacuum Brakes.

The Eames vacuum brake, on the Sydney tramways, is a very simple affair, but an effective apparatus for the purpose Each vehicle has a large iron basin with a flexible diaphragm attached to the periphery, this diaphragm having a large plate washer and chain connection to the centre of it, leading to the brake levers. An ejector is placed on the engine, and two valves are fitted with levers so arranged as to come into one hand of the driver. On opening one valve it admits steam to the ejector which exhausts the pans, draws in the diaphragms, and sets the brakes; opening the other valve admits the atmosphere to the pans and lets the brakes off. This brake is, of course, not automatic, and it is not wanted so for the purpose it is there applied to.

The Eames Vacuum Brake Company have, however, recently introduced an automatic brake, with electric attachments, which has made some good records, stopping a train at 41 miles an hour in 616 feet, but the apparatus is extremely complicated, and hardly seems likely to find general favour.

The Adams brake has probably been examined by every member present, so that it seems superflous to describe it. It will be remembered that the cylinder is contained in a casing or reservoir, and that by means of an ejector on the engine a vacuum is formed on both sides of the piston, which is packed by means of a special rolling india-rubber ring. When the train-pipe is exhausted, a vacuum is formed on both top and bottom of the piston; it therefore drops by gravity, and the brakes are then off. When air is admitted to the train-pipe either by the driver, the guard, or by the train separating, the atmosphere rushes into the pipe; but by means of a small automatic valve it is kept from getting to the reservoir above the piston, and only gets to the bottom of the piston, which it accordingly lifts, and thus puts the brakes on with the pressure due to the area of cylinder and difference of pressure on its two sides. As the air is at a low tension in vacuum brakes, much greater bulk is necessary with this system, both in cylinders and reservoirs, than is necessary with pressure brakes; and as the air has to pass through the train

pipe to set the brakes, the pipe is necessarily very large, being two inches diameter in actual practice. The fittings of this vacuum brake are, however, extremely simple as compared with the Westinghouse brake, and it has also the advantage of being able to control the brake-blocks pressure more gradually and softly, as power can be put on or taken off to increase or reduce the brake power at the driver's will.

Pressure Brakes.

In the Westinghouse automatic brake air is stored in a main reservoir on the engine and passes through a drivers valve to the train pipe, this valve having an opening to the atmosphere. On each vehicle the train-pipe is connected to a small reservoir, a brake cylinder, and the atmosphere through the medium of an apparatus termed a triple valve. When pressure is turned into the train-pipe from the main reservoir by the movement of the driver's valve, a piston in the triple valve is forced up until a passage allows the air to get past and charge the small reservoir, at the same time a small slide valve attached to the triple-valve piston makes a communication between the brake cylinder and the atmosphere, which allows any air in the cylinder to escape, and the brakes come off by the pressure of a spring acting on the front of the brake piston. When the driver lets air escape from the train-pipe by opening it through his valve to the atmosphere the pressure is reduced under the triple-valve piston, which is then forced down by the reservoir pressure, and by its movement opens the slide valve to allow air to pass from the reservoir to the brake cylinder to put on the brakes. A small valve is fitted in the stem of this triple-valve piston which is intended to enable the driver to increase the pressure on the brakes or to graduate it, by graduating the reduced pressure in the train-pipe; the triple-valve piston floating between the reservoir and the train-pipe pressure. This triple valve is a most beautiful piece of design but it is very intricate and complicated. No doubt it can be made to work very gradually in an experiment, although it is the reservoir and not the brake pressure which controls its action. Some of you may remember how beautifully the attendant

manipulated it at our last exhibition with the apparatus comfortably set up as a show, and with no doubt long practice on his part, but from the author's every day experience of the working of the train brakes as a passenger, he is much afraid that this power of gradation is very seldom practically operative, or railway travellers would not be jerked about so much at every stoppage as they actually are. The author understands that there was at the Inventions Exhibition during the time he was there, a triple valve that had a glass front to show the working of this graduation valve, but, however well it may have worked there under the manipulation of an expert, it is doubtful if it really does what is required of it in daily practice, and as it is probable that the rolling stock is more smashed up, and worn out by the shocks of stopping than it is by fair running. It is highly desirable to have a brake that will go on with the maximum of smoothness, and that will give the nicest gradations of power under the control of the driver, both for reducing the pressure on the brakes as well as increasing it, even if it does not act at full power with such a small reduction as the Westinghouse claims to do; that is, to go on full with 20 per cent reduction in the train-pipe.

Owing to the Westinghouse brake using a pressure of from 60 to 80 lbs., it has the advantage over the vacuum brake that a one-inch train-pipe can be used, as against the two-inch pipe used in the Adams vacuum system, and the apparatus is also much lighter for each vehicle.

In some correspondence on railway working in the Sydney press, since the lamentable Peat's Ferry accident, a well-known gentleman complained of the "jerky" stoppages on the New South Wales lines, and referred to the smooth working of the brakes in London, but it appears that some of the lines he referred to have the Vacuum, and not the Westinghouse brake applied.

The "Carpenter" brake is somewhat like the Westinghouse brake but has a very different regulator to the triple valve, and a combined reservoir and cylinder; it can be worked by the air pipe like the Westinghouse and also by electro-magnets for sudden stoppages, it was tested in the recent Burlington trials with good results, for freight train stoppages, and is essentially an Electro air brake.

Leaving for the present the point of smooth and gradual application of the brake blocks, it will be well, after our recent experiences, to consider a quality which it must be admitted is a most important desideratum in brakes intended to be used on railways with heavy and long inclines, such as there are in New South Wales, which quality or power *is not possessed by either the "Westinghouse, Automatic," or the "Adams Brake,"* and that is the power of *maintaining the brakes continuously on, and of increasing or reducing the pressure when they are on*, or *the power of making up for leakage in the reservoirs and brake pistons after the brakes are applied.*

It is not the intention of the author to make this Association the medium of re-opening the question as to the cause of the Peat's Ferry accident. He will not take one side or the other, and he trusts that in any discussion members will not deal with any disputed points of fact that are not positively settled with regard to that matter. One section of the daily press has written strongly for a particular view of the case, and although I believe it has every desire to be impartial, and the writer is certainly well-posted on certain phases of the brake question, his writings are a good imitation of special pleading for the Westinghouse brake. It will be better for *this Association* to look at the whole question of railway brakes from a much broader point of view than the interests of brake proprietors, and consider if any improvements are necessary to prevent a repetition of that accident (which was after all only one that had been foreseen and expected sooner or later), and if improvements are considered desirable, then what direction they should take.

It must be admitted that the Westinghouse automatic brake is a marvellously ingenious invention or series of inventions, and that the triple valve, more especially in its latest form, which exhausts the train pipe into the brake cylinder (probably not yet introduced into the colony), is a triumph of mechanical skill. The Adams brake also, in its more massive and grand simplicity, is the outcome of many minds working for years which have brought it to its present development, but still both these appliances, with all their

refinements, are only human inventions, and it is hard to believe that human skill stopped still when they were brought to their present stage, as some writers would almost seem to expect us to believe.

The "Adams" brake is not complicated, but it is gentle in its action and comparatively slow. The "Westinghouse" brake is more sudden and snatchy in its application, and more handy; but it will not be denied that in either of these systems a brake may leak off from any vehicle, either through defective packing, or other causes, without the driver who is in charge of the train, knowing anything about it. If a driver, with either of these brakes, should have any doubts about the pressure on the blocks, or the way the brake pistons are working, he cannot recharge his small reservoirs without taking all the brakes in the train off the wheels, and it would require some decision of character for a man to deliberately take all his breaks off and leave them standing off for time enough to recharge all his carriage reservoirs, while his train was rushing madly to destruction on a heavy down grade.

It will be granted that the brakes may stop on for hours under the most favourable conditions either with the Westinghouse or the ordinary vacuum systems when they have been so set, but it has been asserted as a positive fact, and has not been denied, *that they have been known to come off in three minutes.*

Let it be assumed that there were undiscovered defects in the brake apparatus of the Hawkesbury train, such defects as no ordinary inspection can exempt everyday machinery from, or that any of the triple valves stuck up, as triple valves do sometimes stick up. (See Board of Trade reports.) Then, under the conditions which existed in that train, there would be such a difference in the available effective brake power as would be sure to manifest itself at once to the driver; and if he, poor fellow, not then knowing what was wrong (as he had no means of knowing it, his guage telling him nothing) if he under such circumstances worked his valve several times in succession in his effort to get a better hold on his train, he would, as a matter of course, lose still

more air and so much pressure as to bring from him the exclamation recorded, by his surviving fireman, "She has got away from us." The author does not say that was what did occur, as he is only discussing the possibilities of these brakes; but it is certain that such things might have occurred then, and they may occur again; and it cannot be controverted that with brakes as now fitted on our railways the driver has no means of knowing the pressure acting on his brake pistons *at any time*, or the pressure in his service reservoirs after the brakes have been on for some time. In fact, the working of both the Westinghouse automatic and Adams vacuum may be almost compared to an attempt at driving a horse with one rein, by having a fixed spur to act in the opposite direction; you pull the rein (figuratively) to pull the brakes off, and charge your reservoirs by charging the train pipe, but you let go of the rein altogether and trust to the spur at the other end in the shape of the reservoir when you let go your train pipe, and *you practically sever all connection between the driver and the brake machinery while the brakes are on*, for there is no further control when the brakes are on and the air out of the pipe. Without discussing the various points that have arisen for discussion out of the late accident, it appears to the author that the Official Board appointed to investigate into the same could hardly have come to any other general conclusion than they did, which may be summed up as a truism somewhat in these words: *In the brake used on that train, there was* (*as there is in all human machinery, more or less*) *an element of danger, and a liability to go wrong in several ways; and on that occasion something did go wrong.*

Now if nothing more could be said, and it was necessary to put up with any such defects as may have caused that accident, after we know of their existence, it would be better to leave the matter severely alone, and allow those gentlemen who have been so ably discussing it in the Sydney press to finish it by themselves, but the occasion seems opportune to bring under your notice an automatic railway brake recently invented in America, which certainly does possess those very important qualities

which are absent in the Westinghouse and Vacuum Automatic brakes, that is:—

(1) The driver never severs his connection with his brakes.

(2) He always knows with what force they are acting.

(3) He can put them on and take them off, more or less, and as much and as often as he likes, without taking them off altogether; and

(Lastly) WHEN THE BRAKES ARE ON HE CAN KEEP THEM ON AND KEEP UP THE SUPPLY OF AIR FROM HIS PUMP TO THE CYLINDERS FOR ANY PERIOD.

This brake is known as

THE "HANSCOM,"

Straight Line Automatic Brake.

The Hanscom brake is the invention of Mr. W. W. Hanscom, of San Francisco, one of the best-known engineers of the Pacific Slope, and it is in operation on the North Pacific Coast Railroad, of California.

This brake belongs to the type which operates by air pressure, a force pump being placed on the engine, the same as in the Westinghouse automatic system, and in its simplest form no reservoir is used. The brake blocks on each vehicle are operated by the motion of a piston in a cylinder, but, unlike other brakes, this piston motion, with the pressure operating on it, is directly and positively under the control of the engine driver, and by means of one valve placed on the engine; and it does not depend on the action of any complicated valves, or stored up energy in connection with each separate vehicle, which valves may act in a different way in each case. The pressure from the pump, through the main controlling valve, acts equally, and at the same time on every vehicle in the train, and thus does away with the violent jerks and irregular action which often occurs with other systems of brakes. The pressure on the brakes in the

Hanscom system can be increased or reduced as much and as many times as is desired, *without taking it entirely off*, as each brake cylinder is in a similar position to the cylinder of any ordinary steam engine, with its two ends directly connected to the compressing air pump, and the atmosphere, through the slide valve, or equivalent mechanism, which serves as the driver's control valve.

The direct operation of the piston in the brake cylinder, is brought into effect by the expedient of using two train pipes instead of only one (but used in an entirely different way to the two train pipes of the early Westinghouse system before referred to), the addition of the simple pipe enabling all complicated arrangements to be dispensed with, and direct communication to be established between the *one* source of air pressure, that is the pump, and either side of the piston in the brake cylinder, as desired.

The driver's regulating valve corresponds to the slide valve of a steam engine, it has a pressure or supply connection to the compressor, and an exhaust to the atmosphere, the two train pipes are continuations of the ordinary *ports* to the two ends of the cylinders, and become pressure or exhaust passages as the valve is moved to and fro.

A pressure gauge is attached *to each port*, and it shows the pressure in each train pipe, at any and all times. The regulating valve is constructed with a slight negative lap on the pressure edges, and thus, when the lever is in mid-position the pressure is slightly opened to both train pipes, and all the brakes are in equilibrium, being kept clear of the wheels by springs in the front of the brake cylinders pressing against the pistons. The two gauges at this time register the same pressure in each pipe.

When it is desired to put on the brakes, the valve lever is moved to open more pressure to the back of the brake pistons, which pistons then move forward with more or less power, according to the amount of port opened and the pressure shown on the gauge of that pipe, and when the pressure is full opened to that side of the piston, the other side is opened to the exhaust, giving the full air pressure on the area of the piston.

To withdraw the brakes the lever is reversed, and a positive pressure in the other pipe then causes the piston to go back in the cylinder, and the brakes are taken off. All the air above a certain pressure (for reasons to be presently described) is then exhausted from the back of the piston to the atmosphere. The pressure gauges at all times showing what is taking place in the pipes.

In order to make the Hanscom brake automatic, the "Brakes-on" air pipe is connected to the back end of each brake cylinder through a small and specially devised valve. This valve will allow the air to pass freely into the cylinder to put on the brakes, but it will always retain a certain regulated pressure, says 15 lbs. per sq. in. at the back of the piston acting to keep the brakes on—that is to say, it will only let out all the pressure above 15 lbs. (or such other pressure as required), when the pipe behind it is open to the atmosphere. When the pressures in the two train pipes exceed this adjusted pressure and it is equal in each, then the brake piston, as before stated, is in a condition of equilibrium, but should any accident occur and sever the connections, or should the guard open his valve on the pipe, the pressure can only be fully released from the front of the piston, and the stored-up power in the back end of the cylinder, which is enlarged to form a reservoir, automatically sets on the brakes at once.

From the foregoing description of the Hanscom brake it will be seen that there is no charging of vessels or storing-up power on each separate vehicle to be brought into operation by the indirect action of delicate mechanism like a triple valve, but that all the motions are directly and positively controlled by a driver's valve of most simple form. No wrought-iron reservoirs are required on the vehicle, as the rear end of the cast-iron cylinder serves for all the reservoir required for automatic action in case of breakaways. In the case of brakes which are worked by separate small reservoirs there is a chance of all or a great deal of the power leaking away on long down grades unless the pistons and other parts are kept in beautiful order and clean, and one vehicle may have brakes hard on and the next one have them only lightly on without

the driver being able to tell that such is the case.* In the Hanscom brake the nicest gradations of pressure can be applied to and withdrawn from all brakes alike at the same time, and any leakage or waste of air can be made up from the pump direct, and the existence of such leaks can be at once detected by the pressure guages.

The North Pacific Coast Railway of California is equipped with the Hanscom brake, and the results in smoothness of working are said to have much surpassed the Westinghouse system.

It is not necessary to say anything about relative cost with other brakes, as the simplicity and non-expensive character of the parts are manifest at once to persons understanding the plans; it would probably cost one-half of the Westinghouse, and it seems hardly possible that a cheaper effectual automatic brake can be desired or devised.

It was said just now that the Hanscom brake in its simplest form was not so sudden or jerky as others in its action in stopping long trains. At the recent Burlington trials the inventor was under the disadvantage of having his gear and train fitted up in a great hurry 2,000 miles from home. He did not stop so quickly as other brakes with electro attachments, but sufficient was shown to prove, however, that it was by far the smoothest working brake on the ground, and absolutely free from the shocks or concussions in the vehicles attending other systems.

Under a form of Hanscom brake, however, especially adapted for quick stops, it is now arranged that all the air still passes from the pump through the driver's valve to the front of the cylinder to keep the brakes off, and it is only necessary, in order to put the brakes on, to reduce the pressure in that train pipe, when, by the action of a small valve interposed between the pipe and the cylinder, the air from the front of the piston escapes, until it is at a correspondingly reduced pressure, *direct into the atmosphere*, the brake acting with the pressure constantly behind the piston. An inspection of this simple valve shows that only one or two cubic

* This paragraph was written only a few weeks before the Peat's Ferry accident.

inches of air have to pass through the train pipe to the atmosphere at the driver's valve besides the contents of the pipe itself. Thus a very small train pipe suffices for very rapid action, and the same sensitiveness is secured for variations of pressure as in the simple form, and the same positive control over the action is secured at all times by the two guiding reins or train pipes which are distinctive features of the system.

In order to make provisions for stopping trains instantly by the simultaneous application of the brakes on every vehicle with slack couplings, the release valve is made with an electro magnetic attachment so arranged that when the driver makes electrical contact by moving his lever to full range, the magnets are excited and open a small leak valve in each apparatus which causes the brakes to go simultaneously on; from the diagram it will be seen that the electro magnetic valve when it moves cuts off connection between the regulating valve piston and the train pipe, and lets out the contained air, thus causing the brakes to go full on at once.

If long goods trains are ever to be stopped instantly it must be by electricity, for with slack couplings the latter part of the train would smash up the front part before the brakes could get on to it. *The Engineer* of the 10th June last (in commenting on the Burlington trials where fifty carriages were stopped from 20 miles an hour in 124 feet by the Carpenter Electro Air Brake), notes that the stored-up energy in a ton of rolling stock at 20 miles an hour or 29 feet a second is $\frac{29^2}{64\cdot4} = 13$ foot tons nearly, and allowing a foot of play in the buffer springs, a car weighing 12 tons would exert a compressive force of 136 tons, and that the quickest acting atmospheric brakes are quite inadmissible for such work owing to the destructive shocks, which must ensue with them. In order, however, to show that this brake is equal to meet such conditions, should they ever arise here, the Hanscom Electro Air Brake is now noticed; but it is in its simple form, easy to work and understand, and almost impossible to derange, that attention is particularly invited now, as being suitable for New South Wales requirements.

It will be very many years before we shall have enormous trains of 600 or 800 tons weight running at great speeds over the plains of this country, as is now the case in America, and consequently there will be no immediate demand for a brake to stop such goods trains in the shortest possible time ; but we have North, South, and West heavy and continuous grades over which it is desirable to make quick running with the assurance of a brake that can be depended on *under the contingencies most likely to arise.* The author does not believe in complicating the brakes of the Colony with electrical appliances at present ; but the cost of an extra train-pipe is very little compared with the security it gives. It does not add to the complication of the brake at all, but it does add amazingly to the assurance which a driver can have of the appliances under his control ; it gives him a brake that he can understand at once without the aid of a tutor, and instead of requiring most elaborate instruction, and having to study up books full of rules to distract him from his attention to other important points in the management of his train he will have his head clear when emergencies arise. The Hanscom brake does thus add much to the security which is afforded to the railway traveller. Under this belief the author has devoted much consideration for a few months past to the subject of railway brakes, and it is curious that he actually referred to the possibility of such an accident as that at Peat's Ferry only a few weeks before it happened.

In conclusion let it be understood that this paper is not written to disparage any existing brakes that have done good service, and the worth of which have already been acknowledged, but rather to further the belief that the people of New South Wales should have in the working of their railways the safest and most perfect appliances that human ingenuity can devise, and that nothing but good can come from the discussion of such a question, by such an association as is here assembled. Up to the present time it appears that for the goods traffic of the New South Wales railways, nothing has been submitted to the Government so cheap, reliable and effective as the Hanscom Brake ; and nothing tha

is in use at present for passenger trains can compare with it for cheapness and efficiency if consideration is to be given to first cost, the comfort of passengers, and security of working.

DISCUSSION.

The President, in opening the proceedings, said it was very gratifying indeed to see such a large and representative gathering there that night. It proved very conclusively that the members of the association duly appreciated and recognised the importance of the subject which was to be brought under their notice. The "brake" question had been before the public for the last few weeks. The subject had excited a large amount of professional and public interest. No doubt this had been caused by the recent lamentable accident on the New South Wales railways, but it would neither be desirable nor necessary, and he thought it would be very questionable taste, to refer to that under the present circumstances. As they all knew, this question had been fought out before, but nothing definite had been arrived at, and the large amount of correspondence which had appeared in the columns of the daily press proved the existence of a healthy rivalry as to the merits or demerits of different kinds of railway brakes. The true object of their discussion was to consider as fully as possible the various appliances at present in use, and to endeavour to make the brakes as perfect as possible. As Mr. Selfe had stated, railway brakes were only human machines, and, so far, they had found nothing in machinery that was absolutely infallible. There were, doubtless, many gentlemen present who had come with the intention of speaking. Well, their time was somewhat limited, and, without attempting to place any restriction upon any one, he hoped those who spoke would condense their remarks as much as possible. It was their desire to hear as many gentlemen speak as was possible, and if speakers would limit their addresses to a quarter of an hour, there would be nothing said, but if they

exceeded that period in any degree he would be obliged to remind them of it. He would conclude by calling upon Mr. Trevor Jones to open the discussion.

Mr. Trevor Jones said when on a previous occasion he undertood to move the adjournment of the debate on Mr. Selfe's paper, it did not quite occur to him that he was incurring the duty of opening the discussion this night, more especially as the subject of railway brakes—although he was an old railway man himself—did not fall within his profession. He would content himself by placing the debate at such a point as they left off on the last occasion. The subject was so extensive that in dealing with it it was quite possible for him to forget some of the more important points which would be alluded to, and for that reason he had placed his remarks on paper. Mr. Jones then said he did not know whether he ought to mention the two sides of the question after what the President had said in his opening remarks.

The President said they were merely assembled there for the purpose of discussing the question of the advantages or the disadvantages of the different kinds of brakes; they were not there to discuss the cause of the accident at Peat's Ferry.

Mr. Jones intimated that he would omit all reference to the railway disaster. He then proceeded to read his remarks, which were as follows:—

He thought it was unnecessary to urge the paramount importance of the subject, that was too apparent to need insistence.

The daily press having a due sense of its momentous nature involving as it did life and limbs, had opened its pages to more communications, and discussed with more pains and thought, the incidence of blame in the recent accident at Peat's Ferry, than was usually devoted to questions of so technical a character.

One of the morning journals had expressed the hope that this Association would debate the question of responsibility in the matter of the above accident. Mr. Selfe on the contrary in the paper that led to this discussion, and subsequently in a letter in the paper, had deprecated allusion to the subject, but was nevertheless unable himself altogether to ignore it.

Mr. Selfe's paper pointed to what appeared to be a serious defect in both of the most popular brakes now used in New South Wales, that was in the Westinghouse, and in the Vacuum, viz., that when either of the above brakes had been on for a short time should there occur a leak anywhere, the driver could not tell what pressure was being exerted on the brake-blocks, excepting by taking off the brakes temporarily.

Mr. Selfe had also put in italics that in neither form of brakes could the pressure on the brake-blocks be modified in the event of leakage from the reservoirs or joints.

Since the last meeting, we had been afforded an opportunity of inspecting minutely a Westinghouse brake-valve with driver's valve, and like all observers, tendered his admiration of the ingenuity displayed in its conception, and had formed the idea that it was the result of a long series of trials and corrections, rather than a direct invention.

That leakage was possible in either brake was of course irrefutable, it must therefore, he apprehended, be considered a defect if the driver could not certainly judge of the extent of leakage without the dangerous expedient of temporarily taking off his brake.

Another point to be debated was that Mr. Adams claimed superiority for the Vacuum brake over the Westinghouse, from its lesser liability to leakage arising from the smaller pressure, 15 pounds as against 60, necessary to actuate it, and moreover, that that pressure acted from outside inwards, whereby the pipe resisted bursting with more force.

While introducing these points for discussion, he held his own opinion, but refrained from giving expression to it in deference to those whose opinions and views he had come to hear.

Mr. Selfe, after enumerating the shortcomings of the two most popular power brakes now in use in New South Wales, and it should be added, expressing great admiration for both, introduced a comparatively new form of brake which claimed exemption or greater exemption than the others from the defects attributed to them, as well as greater freedom from complication, fewer parts, and greater ease of learning its application.

This was the Hanscom straight-air automatic brake which, if it realized all it claimed, promised to be a formidable rival to the Westinghouse and other pressure brakes.

This brake had been in use on the North Pacific Coast railways of North America for many months and was reported to be doing well. It was, however, too soon to form positive opinions just yet, but judging from printed illustrations, we should expect to hear of its success.

It was true that this brake required two air pipes, but by this expedient it secured that which had been deemed a great desideratum in the others, viz., that the driver could with certainty tell what pressure was being exerted on his brake blocks at any minute without taking off his brakes, by simple inspection of the gauges. He thought he had touched upon the principal features under consideration at the time the debate was adjourned, when it appeared to him that the following statements had been made and not disputed.

1. That both the Westinghouse and Vacuum brakes, though almost deemed to be the best extant, had the defect that when once applied, the driver could only judge of the amount of pressure on the brake blocks, by taking off the brakes temporarily and re-applying them, which at great speed on a down brake required great nerve; if there had been no leak, of course the pressure would be the same as indicated on his guage, but if leakage had taken place, then it would be proportionably reduced. The essence of the above seemed to be that if leakage took place in some of the rear carriages it would not be indicated on the driver's guage unless by releasing the brakes.

2. That once applied the pressure could not be modified.

3. That the Hanscom straight-air automatic brake overcame both these defects by means of a double tube. With regard to this last desideratum, he could not see why a double tube should not be fitted to both the other breaks.

The Hanscom brake claimed several other points of superiority, as less pressure, causing less leakage; simplicity of construction and handling—no storage reservoir required—accessibility of parts and many other points.

Without entering into the dispute of the Peat's Ferry accident, it might be permitted to him to give expression to one or two thoughts as to the alleged defects.

That leakage could take place, and did take place after the brakes were applied was undoubted, and that consequently it was true, more or less, to state that the pressure on the brake blocks was diminishing, more or less in all forms of air-power brake from the moment they were applied.

The leakage was not less in brakes worked with lightly compressed air or vacuum, than in those using highly pressed, because the packing of the pistons of brake-blocks was proportionately larger in the lighter, and, therefore, had a larger periphery, which was the origin of loss.

If leakage could take place and power be lost, then it was of great importance that it should be replenished during the time the brake was applied.

Also, on the same assumption, that leakage could take place, say chiefly in the brake cylinder, the theory of exhaustion was conceivable, if the leakage was sensible.

In any case, the driver's gauge should indicate the pressure on the blocks, if the gauge was to be a guide at all, and if the insertion of a return tube would secure this, as well as replenishing and modifying the pressure, then he was of opinion that it should be affixed, if practicable to all brakes.

The great importance of the subject and its complexity had caused him to trespass, he feared, too long on our patience.

Mr. Adams remarked that Mr. Campbell, the representative engineer of the Westinghouse Brake Company, urged the members of this Association at our last meeting to be careful how they formed their opinion on this subject, and not to be carried away by those who profited by the sale of brakes. This was a very eloquent termination to an able speech in favor of the Westinghouse brake, but he would say to the members to be guided by those who profit by the sale of brakes, and not to arrive at any opinion as to the merits of the Westinghouse brake until they had heard what he had to say about it, and *vice versa*. In

his remarks he should endeavour not to waste our time by saying that the Vacuum brake would lift this building, or any other such nonsense, but should confine himself religiously to the subject in hand. At our last meeting he had stated that the Hanscom brake and the Automatic Vacuum brake introduced into this colony were identical in principle, so far as the engine and tender are concerned; but this was denied by a gentleman "who profits by the sale of brakes," and who stated that they were "as wide apart as the poles." The judgment on this point he was quite willing should be pronounced by this Association, and for this purpose he had prepared a diagram sketch, which clearly showed their similarity. (Here followed explanation of diagram, illustrating Hanscom and Automatic Vacuum brakes.) As the author had claimed superiority for the Hanscom brake over the Westinghouse and Automatic Vacuum brakes mainly for controlling trains on steep gradients, he should confine his remarks principally to this particular phase of the brake question. The subject itself was almost inexhaustible, and if, during the present discussion, we succeeded in thoroughly threshing out this particular branch of it, we should have accomplished a great deed. Commencing then with the Hanscom brake, he did not hesitate to say that, in principle, it was superior, theoretically, to both the Westinghouse and Vacuum single pipe systems for the purpose of descending inclines; but there were many other things to be taken into consideration beyond this. The Westinghouse brake, however, either in its automatic or non-automatic form, was the worst possible brake for descending inclines. Before giving his reasons for this statement, it would be necessary to briefly describe the principle of that wonderful piece of mechanism which Mr. Campbell informed us worked better the longer it was in use, and, as our worthy President had happily put it, must, therefore, be like an old fiddle—the triple valve. According to this gentleman, old triple valves should be at a premium, and the instructions to inspect them every three months must only be given to enable the men to see how they are improving.

This was a most important detail, as the brake depended entirely upon its proper action. Without attempting to describe the various parts, we might say that the Westinghouse Brake Company claim that by "simply regulating the reduction of pressure in the brake pipe and causing the motion of the piston and graduating valve to be repeated, the driver can gradually introduce any desired pressure into the brake cylinder from zero up to full power;" but they make no claim to be able to gradually reduce the pressure in the cylinder, nor can they do this. In short, it only graduates the wrong way about. The pressure can be increased in the cylinder but not diminished in proportion as the speed of the train is reduced.

On the New South Wales railways, the cylinders were 10 in. diameter and 12 in. stroke; the reservoirs, 11½ in. diameter and 22 in. long, and had therefore, a cubical capacity of 2284 inches or about 2¼ times that of the cylinder. Assuming a pressure of 60 lb. per square inch stored in the auxiliary reservoirs throughout the system and each piston travelling eight inches of its stroke (in addition to one inch clearance) there would be required at each stroke of the piston 706 cubic inches of compressed air at each application He would now show what would be the effect of a few applications of the brake. Let us imagine that the train at A (see diagram) commences the descent on a gradient of 1 in 40 and that on such a gradient a pressure of 20 lb. per square inch in the cylinders is necessary to control it. Presently, at B, the gradient changes to 1 in 50 where we will assume that 16 lb. per square inch is sufficient to keep the train under control. What takes place? Air is admitted to the bottom of the triple valve piston and forces it up. This allows the air at 20 lb. per square inch which has been in the cylinder to escape into the atmosphere, and then by again manipulating the driver's valve, air at 16 lb. may be admitted to the cylinder to take its place, so that the store of air in the auxiliary reservoirs has been drawn upon to the amount of 706 inches at 20 lb. on the square inch, thereby reducing the store in the reservoirs from 2284 cubic inches, at 60 lb., to the same quantity at 54 lb. on the square inch, so that in one application

and release of the brake—merely to steady the train down our first incline—we have reduced our store of compressed air from 60 lb. to 54 lb. on the square inch. At C, we commence to descend a gradient of 1 in 30 where we shall require an increased amount of brake power viz., 27 lb. on the square inch, but having already 16 lb. in the cylinder we merely add another 11 lb. At D, we again come to a gradient of 1 in 50, where we require, as we have already seen, only 16 lb. on the square inch. To obtain this we must exhaust the 27 lb. from the cylinders and recharge them with air at 16 lb. By manipulating the driver's valve, air at this pressure may possibly be admitted, but how does our pressure stand now? At our last application we had a reserve of 54 lb. on the square inch since when we have had to call upon it for 706 cubic inches at 11 lb. on the square inch. This will have the effect of reducing our store of air from a pressure of 54 lb. to that of 48 lb. per square inch. Coming then, at D, to a grade of 1 in 50 (which only requires a pressure of 16 lb. in the cylinder), we have to release the brakes and re-apply them with this amount. We therefore, throw away 706 cubic inches of compressed air at 27 lb. on the square inch and re-apply the brakes with 16 lb., calling upon our reserve for this quantity and again reducing it from 48 lb. to 44 lb. so that with four theoretically perfect applications of the brake merely to control the train at a uniform speed we have reduced our store from 60 lb. to 44 lb. per square inch, and this may take place within one or two miles and continuing in the same ratio we find that at H, we have not sufficient pressure to apply the brakes with the required force.

We would naturally ask, "Does this actually occur in practice?" The answer was, that exhaustion always took place more or less, but drivers, after a little experience on the mountains, soon began to see that with the Westinghouse brake, it was necessary to husband their strength, and the following was what he had observed. We would notice that on our assumed gradients, we never required less than 16 pounds in the cylinder, therefore, a driver was perfectly safe in putting that in. If he came to a grade requiring another 4 pounds, did he make use of the conical seated

KE ON INCLINES

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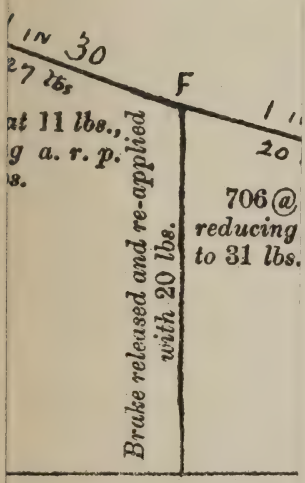


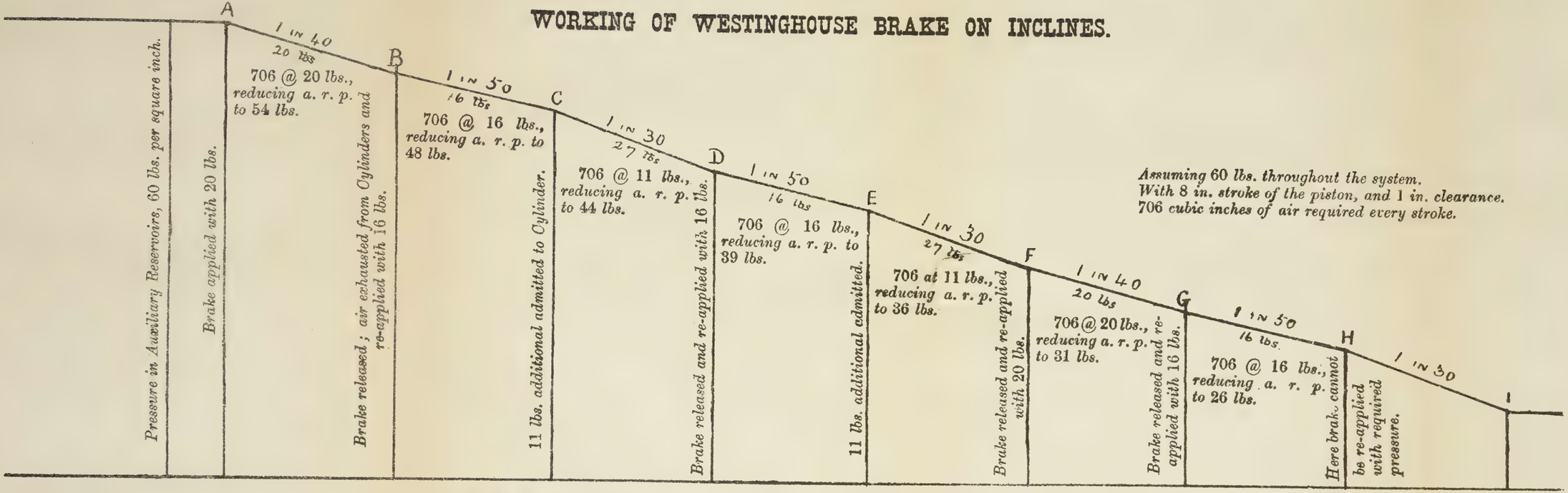
only 23.6 lbs. can be

N.S.W. Railways.
Cylinders, 10 in. diameter, 12 in. stroke.
Reservoirs, 11½ in. diameter, 22 in. long.
Cubical content, 2284 inches.
(2¼ times that of the cylinder.)

DIAGRAM

SHOWING

WORKING OF WESTINGHOUSE BRAKE ON INCLINES.


A
B
C
D
E
F
G
H
I
1 IN 40
20 lbs
1 IN 50
16 lbs
1 IN 30
27 lbs
1 IN 50
16 lbs
1 IN 30
27 lbs
1 IN 40
20 lbs
1 IN 50
16 lbs
1 IN 30
Pressure in Auxiliary Reservoirs, 60 lbs. per square inch.
Brake applied with 20 lbs.
706 @ 20 lbs., reducing a. r. p. to 54 lbs.
Brake released; air exhausted from Cylinders and re-applied with 16 lbs.
706 @ 16 lbs., reducing a. r. p. to 48 lbs.
11 lbs. additional admitted to Cylinder.
706 @ 11 lbs., reducing a. r. p. to 44 lbs.
Brake released and re-applied with 16 lbs.
706 @ 16 lbs., reducing a. r. p. to 39 lbs.
11 lbs. additional admitted.
706 at 11 lbs., reducing a. r. p. to 36 lbs.
Brake released and re-applied with 20 lbs.
706 @ 20 lbs., reducing a. r. p. to 31 lbs.
Brake released and re-applied with 16 lbs.
706 @ 16 lbs., reducing a. r. p. to 26 lbs.
Here brake cannot be re-applied with required pressure.

Assuming 60 lbs. throughout the system.
With 8 in. stroke of the piston, and 1 in. clearance.
706 cubic inches of air required every stroke.

At H required controlling pressure should be 27 lbs., but only 23.6 lbs. can be obtained.

graduating valve? Oh, no; he knew a safer graduating valve than that. His graduating valve was the hand-brake. That was where he got his other 4 pounds. Of course, this punished the engine-tyres unduly, and turning up engine-tyres cost more than carriage-tyres, but it was the lesser of two evils, and he considered that a driver evinced a cuteness worthy of the highest praise in choosing the lesser of two evils, viz., the punishing of engine-tyres rather than the risking the lives of his passengers. A driver could not tell what pressure he had in the cylinders, and could only judge by experience whether he had the train under proper control or not. As a matter of fact, a driver often found it necessary to apply and release his brake several times before he got the desired amount of pressure in the cylinders, and even on the suburban lines we might notice that a driver would apply and release his brake several times before he brought his train to a stand. Then the good-natured pump—if it did not stick—went away right merrily to make up the power wasted. We would, no doubt, be told that as soon as the brake was released, the reservoirs were re-charged. That was quite true, but we had to remember that while re-charging was taking place, the brakes were all off and the train uncontrolled. This might be done with impunity at stations or on the level, but if the gradients were too severe, it was impossible, because in so doing, we let go our hold of the train. In March of the present year, Mr. William P. Marshall, a member of the Institution of Civil Engineers, had read a very able paper at the Society of Arts on "Railway Brakes," and had stated that during a recent visit to the United States of America, "he had observed that the intermediate (or triple-valves) were all thrown out of action in descending the Rocky Mountain incline, and the brakes worked non-automatically during the descent. On his return to England, he wrote to the Westinghouse Brake Company in London on the subject, giving them the particulars of what he had observed on the Rocky Mountain incline, and the answer received from them was that "the use of the non-automatic brake for descending long inclines is not at all necessary. On some lines in the United States there is still the practice of using the non-automatic brake

for descending grades, but we think this is owing to the fact that the direct pressure brake was very largely used there before the automatic form was adopted." As this did not accord with what had been observed upon the line, he applied to the locomotive engineer of the line, asking the reason for the intermediate valves being thrown out of action in descending the incline, and his reply (which was given in the paper) is that :—" Auxiliary reservoirs cannot be re-charged without releasing all the brakes on the train, and the train will, during this short time of release—fifteen to twenty seconds—gain such a speed on a down grade of 211 feet to the mile (or 1 in 25) that it is nearly impossible to regain control over it, especially when the rail is bad. For this reason, the triple valves and auxiliary reservoirs are cut out on steep grades down." Here we had two reasons given for the converting from the automatic to the non-automatic Westinghouse for descending long and steep inclines, and they may be said to be "as wide apart as the poles." The one was given by the engineer responsible for the safe working of the trains, the other by those who "profit by the sale of brakes." It appeared to him that the reason given by the Westinghouse Brake Company for changing from the automatic to the non-automatic brake, viz., "that the non-automatic was largely used before the automatic was adopted," was altogether too thin. What did the change necessitate? It necessitated (on arriving at the summit of the mountain) a man going to each vehicle and turning a three-way cock, by which he shuts off communication to the triple valve and opens a direct passage between the cylinder and main pipe. It meant that the driver had to work his brake-valve the reverse way to what he had done a few minutes previously. It meant that in the event of a burst hose-pipe occuring during the descent, that the train was no longer under the control of a continuous brake; and we should remember that the last Board of Trade Returns issued, for the six months ending December, 1886, contained no less than 352 cases—all of which occurred in traffic—and he thought we would agree with him that there was some reason other than that "the non-automatic was largely used before the automatic was adopted." Pursuing the

same line of argument, why did they not revert to the use of the hand-brakes, which were also largely used before either the automatic or non-automatic were adopted. He was aware that latterly a statement had been published that the locomotive engineer stated that they were now using the automatic brake on their lines, but whether they had reduced the exhausting difficulty by putting on larger pumps and reservoirs, as they had done on the Hungarian mountain lines, or had resorted to other devices, we were not at present aware, but there still remained one very ominous fact to face. The Paris, Lyons, and Mediterranean railways passed through some very mountainous country, and some years ago they had adopted the Westinghouse automatic brake. Shortly after it had been introduced, the engineer of these railways, M. Henri, had found it necessary to run an additional pipe through the train to obviate this defect in the Westinghouse system, and to this day all the trains were running with the Westinghouse brake, as improved by the locomotive engineer, M. Henri, with the re-charging pipe.

Now, although this overcame the difficulty in a measure, it added further complications to an already complicated piece of mechanism, but this appeared to be the usual fate of the Westinghouse brake. Too high a pressure was carried by drivers, causing flats on the wheels, and inconvenience to passengers, and the "governor" was introduced to prevent the air pressure getting too high. Hose pipes did burst, causing delays and accidents, and a double set were introduced, with the addition of two valves, four seatings, and two extra couplings for each vehicle, to obviate this difficulty. But these would sink into oblivion when we considered that a series of metallic pipes, with six moveable joints to each carriage were introduced, and to prevent waste of air and obtain quicker action, a new triple valve, with additional valves and springs had been schemed, adding "a sum of more to that which hath too much."

What the end of all this would be it was impossible to say, but it would be well if the inventors of the Westinghouse brake

were to remember the words of one, but for whom we should probably not be here to-night. He meant James Watt. His words were simply prophetic, and as true to-day as on the day he uttered them : "In all things, but proverbially in mechanism, the supreme excellence is simplicity."

Mr. Shellshear said that in the paper Mr. Selfe came forward as the special pleader for the Hanscom brake, and under the circumstances it was not to be wondered at that he should endeavour to show up the Westinghouse and Vacuum brakes in the most unfavourable light, and when comparing these with the Hanscom brake they always came out second best in his estimation. There were a few matters in the paper which were so much at variance with the experience of every-day working, that he thought it necessary to draw attention to them. Mr. Selfe made the following statement : "This non-automatic brake is going out of use, although it is, in some respects, much safer for mountain lines than the automatic brake." For any man to advocate a non-automatic brake for mountain traffic was, to say the least of it, the height of madness ; for with the non-automatic system—either pressure or vacuum—a bad leak, a coupling separating, or a burst hose pipe, would deprive the driver of all control over the brakes of his train, to say nothing of a coupling breaking when ascending a steep grade. The whole tenor of the paper was to try and prove that the Automatic Pressure and Vacuum brakes were not suitable for long down grades, but what was the experience of the working of these brakes on long grades. If Mr. Selfe would refer to the Engineering of 27th of May, he would find that some of the steepest and longest grades in the world had been worked successfully for years with the automatic pressure brake, and Mr. J. N. Choate, of the Pacific Railroad, who had used this brake for some years on continuous grades of 1 in 25, for 19 and 30 miles at a stretch, stated that : "Since using it I do not know of a single instance in which any damage has occurred through its failure, or of a time when it has not worked properly, when handled by competent persons."

The extent to which the automatic pressure-brake was used on these steep grades on the Rocky Mountains, would be seen from the following tables :—

UNION PACIFIC RAILROAD.

30 miles	...	...	...	...	of 1 in 25
19 miles	...	...	...	...	of 1 in 25

ATCHISON TOPEKA, AND SANTA FE.

5 miles	...	...	...	...	of 1 in 28½
11 miles	...	...	...	...	of 1 in 50

DENVER AND RIO GRANDE.

21 miles	...	...	...	...	of 1 in 25

The Northern Pacific worked three grades of ten miles each of continuous 1 in 25, and were shortly going to use this brake on grades of 1 in 18. Nor was the successful experience of the use of the Automatic Pressure brake confined to America, for we found that it was in successful daily working on the severe inclines on the Paris, Lyons and Mediterranean Railway, and that trains run down the long inclines on the line just named without any difficulty being felt. Mr. T. E. Harrison, of the North Eastern railway, who had, perhaps, the largest experience in the use of the Automatic Pressure brake of any engineer in England, stated that "it has been found especially useful for working steep inclines, of which there are many on the North Eastern system; in some the gradients being as steep as 1 in 37," one of the grades on this line being five miles in length altogether. The Automatic Vacuum brake had not been used to any great extent on steep down grades, yet he understood that on some of the long down grades of 1 in 50 in Victoria, this brake was now in daily use, and giving satisfaction.

Again, we had the experience of this colony, where the same brake had been used successfully for years on the steep grades over the Mountains, and if we took the Melbourne express, which had been worked over the steep grades of the Southern line at an average speed of something like 30 miles an hour for years without accident, he did not think we could have a stronger proof of the absurdity of Mr. Selfe's argument, that this brake was not suitable for working heavy grades.

Looking at the brake question from a broad standpoint, the case was reduced to this, to use the words of Mr. Clement E. Stretton: "That at the present time there are but two systems that can be considered efficient, or that are at all likely to come into permanent use—viz.:—the Westinghouse Automatic air brake, and the Vacuum Company's, or Gresham's automatic vacuum brake." Although, to say that either of these systems was perfect, would be to announce that mechanical skill was played out. The two systems had their weak points, which were capable of being more or less improved upon. The one system also had certain advantages over the other, and *vice versa*. Thus, in the case of the Westinghouse, the pump might be simplified with advantage, and there was the trouble of an occasional burst hose pipe. The triple valve, although spoken of by Mr. Selfe as being "very intricate and complicated," was, after all, only a simple piston with a slide valve working on one spindle, which was certainly not calculated to puzzle or over-tax the brains of an apprentice boy, who took the trouble to try and understand. The rest of the apparatus was simple, light, and with even slight attention, was not likely to give trouble, or be costly to maintain in a state of efficiency. As to the Automatic Vacuum brake, the apparatus was simple, but it was not so quick in its action as the pressure brake, and was undoubtedly a good steam eater. Mr. Selfe insinuated in his paper "that the Westinghouse brake had been known to come off in three minutes." If there was any truth in this insinuation, it could only be said that it did not reflect very great credit to those in charge of it wherever such a thing occurred. Although there was no doubt that neither the Pressure or Vacuum brakes would remain on for ever, but would leak off in time, according to the state of the piston packing, but the packing in either system should retain the air long enough for all practical purposes, if it received a moderate amount of attention. A serious leak in the packing in either system would be detrimental to efficiency, although it would be of more importance in the case of the Vacuum than the Pressure brake, as the latter could be re-charged with far greater rapidity from the main reservoir than was the case

with the Vacuum brake, where the air had to be exhausted by the large ejector. A statement had been made at the last meeting that the Vacuum brake would remain on for five hours before leaking off, but he should very much doubt if such was the case, and it would be interesting to see a gauge fitted on the vacuum chamber of some of the cattle trucks fitted up with the Vacuum brake some time back. From the rapidity with which rubber deteriorated in this climate, he would be very much surprised if the cylinders of these trucks would now retain the vacuum for fifteen minutes with the brake applied, unless new packing rings were put in. From the fact that a large amount of rolling stock in England had been fitted up with the now obsolete Non-Automatic Vacuum brake, there was little doubt that this stock, on the ground of economy, would be converted into the automatic system, as the expense would simply amount to a new brake cylinder and a different form of ejector for the engine.

But in the case of our railways, the wisdom of complicating the working by introducing two or more systems of brakes would be very questionable, more especially as the practice of running mixed trains was on the increase, and there was certainly no advantage in the Hanscom or Vacuum brakes that would warrant such a complication on the one hand, or the general substitution of either of these brakes for the one which had been used with marked success for so many years on our passenger stock.

To return to the Hanscom brake, it was certainly amusing to read Mr. Selfe's remarks as to the cost of this brake. He stated "it would probably cost one-half of the Westinghouse." Now, comparing the two brakes, he was afraid Mr. Selfe would not get much change out of the transaction if he undertook to supply his brake at that price. He thought he would be rather nearer the the mark in his estimate if he put it at about 50 per cent. more than the Westinghouse. The Hanscom brake in its simple form was admittedly slow in its action, and it was interesting to see how Mr. Selfe proposed to make it quicker in action by introducing rather a bad copy of the so-called intricate and complicated

triple valve as well as electrical appliances. He had already extended his remarks to perhaps an undue length, and he would simply conclude by saying that it was a wise man that stuck to a good friend when he had got one and that the Automatic Pressure brake, although capable of being improved, was one of the most valuable and trustworthy appliances that science had introduced for the safety of the travelling public.

Professor Warren, stated that his remarks would be mostly of a general nature. He thought Mr. Selfe was to be congratulated for having brought before the Association a subject of so much importance, not only to engineers, but to the general public. With regard to the Burlington brake trials, referred to by Mr. Selfe, he considered that the experiments on brake p ressure speed, and distance run after the application of the brakes, to be a most valuable addition to the data obtained by Captain Galten on this subject. The author had already explained to us that the competing brakes were the Carpenter, the Westinghouse and the Eames, the Hanscom having practically withdrawn from the trials after a few unsuccessful attempts. The most remarkable stops were made by the Carpenter and Westinghouse brakes, with the valves actuated by electricity, the former stopping a train—consisting of thirty-three loaded and 17 empty trucks—travelling at twenty miles an hour, in 172 feet; and the latter in 200 feet. It was found that when electricity was used to actuate the valves there was less shock felt in the rear car, and merely an elastic surge of the train felt in the front car. When, however, the valves were actuated in the ordinary way, by means of air, the shock was considerable, notwithstanding the fact that the distance travelled after the application of the brake, was three times as great. These were important facts and clearly demonstrated that to stop a freight train of fifty cars in the shortest distance, it was necessary to apply the brake blocks as nearly as possible at the same instant to every car if we would minimise the damage to rolling stock; and it was most desirable that this should be effected by the same medium as that used for applying the brake under ordinary circumstances, namely, air. He (Professor Warren) considered that

electricity should not be used as it would be uncertain in its action when operated by ordinary drivers, and quickness of action could be obtained by other means. The retarding power necessary to stop a train of a given weight and speed on a level or on an incline may be calculated with great accuracy in the following manner.

Let x = the percentage of retarding effect on a level line
,, x_1 = the additional percentage of retarding effect on a gradient due to the force of gravity
,, X = the total percentage of retarding effect on a gradient
,, d = distance run, in feet, after application of brake
,, n = gradient expressed as 1 in n feet
,, v = velocity in miles per hour
,, p = pressure on brake blocks
,, a = co-efficient of friction

On a level road Captain Galton found that $x = \frac{3{\cdot}34}{d} v^2$ and $x_1 = \frac{100}{n}$

and therefore $X = x + x_1 = \frac{3{\cdot}34}{d} v^2 + \frac{100}{n}$

So that the total retarding force on a level line, or on a gradient, may be easily calculated. The brake pressure was found by dividing this percentage of retarding force by the co-efficient of friction, thus :—$P = \frac{X}{a}$ or $= \frac{x}{a}$ according as the stop is effected on a gradient or level line. The co-efficient of friction was, however, by no means an easy factor to determine, nor had Captain Galton completely solved the question for all cases. It was, however, proved by Captain Galton—

1. That for a given amount of friction between the brake-blocks and wheels, the force required to skid the wheels is independent of the velocity.
2. That the co-efficient of friction diminishes as the speed of the train increases and with the time the brake-blocks are in action.

Hence, it followed that the wheels would require a much greater force to skid them at high velocities than at low velocities, and a train which might not be skidded when the brakes were first applied with full force, would certainly be skidded as the velocity of the train became gradually reduced, unless the pressure on the brake-blocks was released. Taking all these facts into

consideration, it would be seen that in order to calculate the brake pressure which would stop a train, under given conditions as to speed and gradient, it was necessary to determine the average co-efficient of friction for the length of stop in question, which could best be done by plotting the results of the experiments which had already been made as ordinates and abscissa for co-efficient and speed respectively; bearing in mind that the co-efficient would be increased as the speed was reduced, and reduced as the time taken to stop the train increased.

If this co-efficient be divided into the percentage of retarding force found by the former, the result would be the minimun brake-pressure, that is to say, the brake-pressure that would be necessary if every wheel in the train was supplied with brake-blocks. It generally happened, however, that there were a number of wheels which were not braked, in which case the percentage of retarding force which would be necessary to counteract the momentum of the unbraked revolving wheels, had to be added to the percentage found by the formula referred to, dividing by the average co-efficient of friction. In fitting a train with a continuous air-brake, we had so to arrange the size of the brake-cylinders and the leverage, whether for air or vacuum, that the pressure on the wheels was the greatest possible, which would just not produce skidding under ordinary circumstances. In the experiments made by Captain Galton, on the Lancashire and Yorkshire railways for example, the maximum brake-pressure had been 90 per cent. of the weight of the carriages braked. In Victoria and in South Australia, the maximum brake-pressure was also at 90 per cent. In New South Wales it was somewhat less.

With regard to the brakes described in the paper. The advantages possessed by the Hanscom brake, had been fully explained by the author, and the Automatic Vacuum brake, and the Westinghouse automatic brake had also been fully considered. The two latter brakes had gained such notoriety lately in this colony, and had been so fully discussed in the *Daily Telegraph*, that they must be very familiar to every member present. During the last three weeks, he had an opportunity of enquiring into the

working of the Vacuum and Westinghouse brakes in Victoria and South Australia. As Chairman of the engineering jury at the Adelaide exhibition, he had to deal with these brakes. The jury, however, did not feel themselves called upon to decide a question from exhibition models, which was a disputed point with engineers. The question could only be settled in a satisfactory manner by means of experiments on running trains coupled with the experience which had been gained in the use of the brakes both here and in other colonies. The jury decided that each should have a first award, although one member protested against the decision, he being in favor of the Vacuum, receiving a higher reward. A few experiments had been made on the exhaustion of the auxiliary reservoirs in the exhibition model of the Westinghouse brake. A few experiments had also been made on the time taken to fill the auxiliary reservoirs. In order to see how these experiments correspond with those made on trains, he had made experiments on the presence of Mr. Thow, locomotive engineer, South Australia, and Mr. Roberts, assistant locomotive engineer on a train of nine carriages, 315ft. long, measuring from tender buffers. It took 5 full manipulations to exhaust the air in the auxiliary reservoirs, from 75 to 25 pounds per square inch with the donkey going full speed, and the pressure in the main reservoirs, varying only 2 or 3 pounds from 85 pounds during the experiment. It had taken 6 minutes to charge the auxiliary reservoirs from 25 pounds per square inch to 75 pounds per square inch. The pressure in the auxiliary reservoirs had been measured by means of new Westinghouse gauges placed on the front and rear carriages. The gauge in the last carriage had taken a few seconds longer than that on the first, to indicate the same pressure. The experiments had been repeated several times with similar results, and no signs of leakage could be detected. The experiments on the train in the Redfern yard, had given about the same results with regard to exhaustion, but the reservoirs under the carriages had been filled in half the time. The exhaustion had taken much longer in the exhibition model, and the filling had been effected in 1 minute and 25 seconds for 9 reservoirs, and 3 minutes for 15 reservoirs.

An experiment had also been made on the exhibition model of the Vacuum brake, in order to test the leakage past ball-valve or rolling ring in cylinder, with a view to its efficiency when used on long inclines. The Vacuum had been destroyed in the main pipe from 22 inches to 10 inches, and the pressure on the gauges attached to the reservoir above the vacuum cylinders had been carefully noted. After two hours the greatest reduction of pressure was found to be four pounds. The gauges had been carefully watched by one member of the jury during the whole time.

Mr. Thow, locomotive engineer, South Australia, had thoroughly tested the leakage due to a total destruction of the vacuum in the main pipe, with the result that in the worst case it had taken two hours to leak off. If one half the time which was necessary to be expended in the examination of the parts of the Westinghouse brake would be taken in a similar examination of the Vacuum brake, there need be no misgiving on the leakage question raised by Mr. Campbell, the engineer for the Westinghouse brake. The ejector in ordinary working would overcome the leakage completely. He had examined an application of the Vacuum brake to freight trains, in company with Mr. Thow, which had given excellent results with regard to economy and efficiency. He had examined the Westinghouse brake as applied to trains in Victoria, in company with the Engineer, Mr. Allison Smith, who had thoroughly organised this department. The parts of the brake were periodically examined, and the drivers were instructed and examined in the use of the brake. He said that he rode down the Picton incline yesterday on the engine of the Melbourne express, and saw the Westinghouse used in a most skilful manner by the driver.

With regard to the exhaustion of the auxiliary reservoirs. It had never been contended that the auxiliary reservoirs must necessarily be entirely exhausted when the brake was used on long and steep inclines, but that they might become entirely exhausted by the unskillful use of the brake, and that under any circumstances, they must be partially so. He quite agreed with Mr. Selfe's remarks on this subject, that the brake-power could be exhausted

in a running train was now a fact; and a very difficult one for the Westinghouse Company to explain away, even if we ignored the lesson taught, us by the Peat's Ferry disaster.

The Vacuum brake on the other hand could be thoroughly relied upon to develope its full power in 20 sec., and to maintain that power for two hours or more if necessary. When the vacuum was partially destroyed on an incline, it was equally reliable. It had also the advantage in simplicity.

The President asked Mr. Campbell, the engineer for the Westinghouse Brake Company, if he would not like to speak.

Mr. Campbell said it would not be fair for him to speak just now.

The President said he was sure it would be fair for Mr. Campbell to speak. There were a number of gentlemen present who desired to hear him. The chances were that the discussion would be further adjourned. As a matter of courtesy to Mr. Campbell they would like to hear him speak, but if he did not intend to do so, he (the speaker) would call on someone else.

Mr. Campbell said he had been so much engaged since the last meeting, that he had not had an opportunity of preparing diagrams, but if the discussion were postponed, he would in all probability execute some diagrams. He understood that the Peat's Ferry accident was not to be gone into. The cause of the accident had been referred to pretty plainly, so if it were to be gone into, he would like to deal with it properly. He was sorry he was not present when Mr. Adams spoke. He believed that he had said that the Westinghouse brake could not be worked down an incline of that character (referring to diagram) without accident.

Mr. Adams (decisively): No!

Mr. Campbell: Well, a few days ago, it was reported that the driver started at the top of the incline with 80 pounds, and it was 70 pounds when he reached the bottom. He did not, however, mean to say that the Westinghouse brake could not be exhausted. He thought any piece of mechanism using a fluid, could be exhausted. So far as the brake power on a train went, he had to admit he could scarcely follow Professor Warren's figures; but he

would like to avail himself of the opportunity of putting down a few figures. He then gave a series of illustrations regarding the retardative effect of brakes upon a train going down an incline.

Continuing, Mr. Campbell said as regarded the Westinghouse and Vacuum brakes, at the previous meeting he had given some figures which he had taken from the Board of Trade Returns. He found from the figures supplied by the Board of Trade, that the Vacuum brake, which was being pushed very much in this colony just now, failed twice as often as the Westinghouse brake did. Now, he would put a question to Mr. Adams. He (Mr. Campbell) wanted Mr. Adams' acceptance or denial of these figures. He would like to have a commission composed of members of this association to sit on the matter. Why, on looking through the book he found that there were seven instances in which the driver failed to get a vacuum at all.

Mr. Adams here asked Mr. Campbell if he had the latest returns from the Board of Trade.

Mr. Campbell did not think he had the latest returns that had been issued.

Mr. Adams said, if what had been stated by Mr. Campbell were true, he could not alter it.

Mr. Campbell said that if the Vacuum brake, with all its simplicity, failed twice as often as the Westinghouse brake did, it showed that there must be something inherently weak in it. He had taken an average of the figures given, and if the Board of Trade Returns were true in stating that the Vacuum brake failed twice as often as the Westinghouse brake did, where was its simplicity. These figures should be gone into. He would be very happy to go into Mr. Adams' publications singly—one after the other—and if he could not prove that what was asserted was false, he would be prepared to forfeit anything they liked.

Mr. Granlund, the representative of the Westinghouse Brake Company, spoke in defence of that particular form of appliance. He thought that for many reasons the Westinghouse brake might be considered to be very much better than the Vacuum brake. The brake itself—that was the three parts which constituted the brake

—was very simple. If there were any dispute about the action of the triple valve, they would show by ocular demonstration what it could do. The Westinghouse Brake Company had always courted publicity, and their trials were open to the public. They were not secret trials. They would like Mr. Adams to fix up an apparatus; they would ask Mr. Selfe to do the same; and they would also do so on their own account.

A member: Who is to pay for this?

Mr. Granlund: Well, we will pay for ourselves, and let the others pay for themselves. Let the thing be fairly tried and tested, and then, if we are worsted, we will submit; and if we are beaten, we will "draw in our tail," pay expenses, and go home.

Mr. Granlund then made a lengthy reference to Professor Warren's figures, and said it was patent to everybody that on a running train one application of the brake would be sufficient to stop it, if the train were properly fitted.

Professor Warren: Quite true.

Mr. Granlund: In no country in the world was the rolling stock fitted with such a low brake power as in New South Wales. It was larger in Victoria than in this colony. An automatic continuous brake was mainly an emergency brake—one to be applied in the quickest time and at the shortest notice. In the Peat's Ferry train, there were four carriages fitted, out of nine and with that low brake power they would be very much inclined to say that if any speed over twenty-five miles an hour were got up, the brake would not be sufficient for the train. The Westinghouse Company were only responsible for the brake. The Railway Department were responsible for the fitting of the train. He only wished to add that the company which he represented would like to see full, fair, and public trials. They did not go by mere assertions; they wished to have facts and proof of those facts, and they were quite willing to bring that about by any means in their power.

The President then said that the hour was getting late, but if any of the members wished to speak they could do so. He might mention that special reference had been made to some trials that

took place on the previous saturday, to which (on behalf of the Association) Mr. Pollock and himself were invited. As special reference had been made to these particular trials he had no hesitation in making a statement as to what actually took place on that occasion, but he considered that the object of this meeting was to discuss Mr. Selfe's paper, and he did not feel justified in making any mention of it just then. But at the same time, on behalf of the Association, he would be very glad to make a statement, and Mr. Pollock or himself would be very pleased to answer any questions that might be put to them on another occasion.

Mr. A. D. Nelson said it was not his intention to say anything upon this question that night. He had been rather inclined to take part in the discussion, but after the remarks of their President, prior to the renewal of the debate, he had had the wind completely taken out of his sails. He moved that the discussion be adjourned.

DISCUSSION RESUMED.

A sketch of the new triple valve used in the Burlington brake trials was exhibited by Mr. Norman Selfe.

The President called upon Mr. A. D. Nelson, who proposed the adjournment of the discussion, to open the debate.

Mr. A. D. Nelson said he found that he had been placed in a rather false position from the simple fact that, when at the previous meeting he moved the adjournment of the debate, he did so on behalf of the President. Therefore he hardly thought it fair that Mr. Cruickshank should call upon him. However, with the permission of the gentlemen present, he would proceed to deal with a few matters worth touching upon. He then referred at some length to the position the members who might wish to speak were placed in by the request of the President, which was in effect that they were to abstain from touching upon the recent accident at Peat's Ferry. He then proceeded to show the difficulties the members laboured under in attempting to discuss the question of the railway brakes, when the main feature in connection therewith was debarred from discussion. There could be no denying the fact that the great interest taken in this

debate was to a very large extent due to the accident at Peat's Ferry, as they could not drive away the fact that it was this accident, and it alone, about which they were talking in the main. Members of the Association would, he thought, admit that, despite Mr. Selfe's statements to the contrary, the question of the accident was dealt with, and, in a great measure he might almost say, exclusively dealt with, in the paper. However much members might try to lead themselves into the belief that they were discussing the brake question from a broad standpoint, it was patent to everyone that the Peat's Ferry accident was uppermost in their minds as the cause of that accident, and the public discussion and comment which it had been the means of eliciting was beyond doubt the reason why the discussion on Mr. Selfe's paper had extended for so lengthened a period; and it was also the reason why the members of the Association took so much interest in it. To show that Mr. Selfe, in reading his paper, had to all intents and purposes dealt with the question, he proceeded to read several extracts from the paper. He thought that there was not the slightest necessity to quote extensively from scientific papers, which had been in a measure dealt with by previous speakers, but he would like to draw our attention to the report written by Mr. J. E. Harrison, engineer for the North-Eastern Railway Company in England, to his directors, expressing himself in very forcible language.

He would call our attention to the fact that the Tebay line, a portion of the road upon which Mr. Harrison was engaged, was the steepest grade in England, and when we took into consideration the report written by him after his extensive experience and experiments on that line, he failed to see that with such a report as this, coupled with many other similar reports, how we could arrive at any other conclusion than that the Westinghouse brake was the safest for passenger or goods traffic. In concluding his remarks, he would note the last extract he had read from Mr. Selfe's paper, in which he stated that there was a liability to go wrong in several ways, and to which he alluded. Many did go wrong beyond doubt; but we were told in the press what it was that went

wrong, and from all the records he could find, dealing with the question of brakes, he had been unable to find a theory laid down based upon the principle of *exhaustion*. While he admitted that there was a possibility under certain circumstances to exhaust the air out of the small receiver, he maintained it was not possible to do so by working the brake fairly, with ordinary care, or with ordinary intelligence, and he maintained that any man who was placed in such a position—to have control of the brakes of a locomotive engine and train—who would be guilty of such negligence as to wilfully pump the air out of the receiver and wreck his train, he would be just as guilty as though he had run his engine into the stops at a station with 130 lbs. pressure on his cylinder. This was the point he wished us to clearly understand, and although he had had the opportunity of witnessing various experiments with the Westinghouse brake, he could not arrive at any other conclusion than he had stated, viz., it was impossible, with ordinary intelligence, with ordinary care, and that it was not possible, unless some tricky movements of the valve were resorted to, to extract the air from the receiver.

Mr. Fischer said that it was not his intention to discuss the merits or demerits of the Westinghouse and Vacuum brakes, either as compared with the Hanscom brake or amongst themselves, but he rose to correct an omission on the part of Mr. Selfe, which might possibly lead some of the members to the erroneous conclusion that, besides the railway brakes just mentioned, there was not at least one other brake worthy of consideration. That Mr. Selfe was not aware of the existence of the brake to which he was about to refer was hardly credible, as it had been exhibited at the Inventions Exhibition held in London in 1885, and during Mr. Selfe's recent visit to England. This gentleman's paper being (judging by its title) supposed to deal with railway brakes generally, he found it necessary, in common fairness, to supplement his paper. He referred to the "Heberlein Automatic Friction Brake." The time allowed to speakers to-night being necessarily limited, it would not be possible for him to give a full description of this brake, and should therefore refer those who took an interest in

this subject to the *Engineer* of April 2nd, 1886, where a full explanation of its working, as well as diagrams, would be found, and from which he proposed to quote hereafter.

This brake belonged to the class of chain brakes, which Mr. Selfe (after informing us of his own failure to design a satisfactory apparatus of this description), summed up as follows:—"*Since then the author has paid no attention to chain brakes, although there are several varieties that have had their day, but they are fast becoming things of the past.*" Now this assertion was not warranted in the face of the opinion expressed by the Jury of the Inventions Exhibition, who had placed the Heberlein brake on exactly the same footing as the Westinghouse and Vacuum, viz., they awarded a gold medal to each of them, and of which brake the writer in the *Engineer* said:—"That through the improvemenls made since the introduction of the Heberlein, it has been converted from a very bad brake into a *very good one.*"

The Heberlein brake had all the good points of the air brakes (even including the Hanscom), while it had at least two additional features to its advantage over the others:—(1) It had no pump or ejector, which could get out of repair, the brake being actuated by the momentum of the train; and (2) It was not an absolute necessity to have all the vehicles of a train fitted with air pipes to make the brake act through to the last vehicle, which was generally a guard's van; but vehicles with or without brake appliance could be mixed up at will, and by simply passing a spare length of rope over them, the brake could be actuated from any part of the train.

The Heberlein Brake could be applied to any degree desired, put on or taken off as often as the driver thought fit, and could be graduated to a nicety, so as not to inconvenience passengers, without exhausting the motive power; for the reason that while the train was in motion the motive power was at hand.

As to relative cost, he was of opinion that the Heberlein apparatus could be fitted for about half the money of any other automatic brake known.

The Heberlein brake had been adopted for all the Prussian subsidiary lines, and was also in use (among others) on the following railways and light railways:—Jura-Berne-Lucerne, Swedish States, Bahia and San Francisco, Gefle-dala, Harz-Mountain, Saronno-Como, La-Sarthe, Kiel-Flensburg, Saxon States, Orel-Witepsk, La Guayra and Caracas, Brunswick, Java, Oldenburg, Puerto-Cabello and Valencia, Mecklenburg-Southern, Arezzo-Fossato, and in England on the Colne Valley Railway.

A few more quotations from the *Engineer* might be justified, as illustrating the use of this brake on a very heavy line. Mr. James Livesey, engineer-in-chief of the La Guayra and Caracas line, writes:—"For a distance of nearly 20 miles there is a continuous gradient of 1 in 27, with a succession of curves and reverse curves of 130 feet radius from one end of the line to the other." The trains on this line are fitted and worked with the Heberlein brake.

On the Prussian State railways about 3000 miles of line were either open for traffic or under construction, on which the Heberlein brake was in use or to be used exclusively as the normal brake.

Mr. Selfe, in his concluding paragraph, said that:—"Up to the present time, it appears that for the goods traffic of the New South Wales railways, nothing has been submitted to the Government so cheap and effective as the Hanscom brake; and nothing that is in use at present for passenger trains can compare with it for cheapness and efficiency, if consideration is given to first cost, the comfort of passengers, and security of working;" to which he would like to add, *that before any brake was adopted for the goods traffic on the N.S.W. railways, careful enquiry into the merits of the Heberlein brake should be made*, and he did not hesitate in saying, that for this particular work, the "Heberlein" would beat any of the other known railway brakes.

Mr. H. W. Kerle remarked that there was one point which had been brought forward very prominently (that was the exhaustion theory), whilst everything else had been left out in the cold. The question of merit in brakes did not lie in one particular point.

The real question was which was the best on the whole. He had no doubt that the Westinghouse brake could be exhausted. Any machine designed to do certain work could only perform or carry out that particular kind of work, and if it were improperly used or applied it must lose its effect. They were shown a sketch or diagram on the previous evening explaining how the Westinghouse brake would act on a falling grade, and that, after a certain number of applications, the pressure in the reservoir could be reduced very considerably; in fact, it could be reduced so low as to be useless. But that was a one-sided diagram altogether. There was nothing shown as to when or how long the applications were made, or whether they were allowed time to recoup themselves after the brake was taken off. Taking the Hanscom brake in this particular instance of descending grades, there was no doubt but it could be more advantageously used than the Westinghouse brakes as at present fitted. Respecting the Vacuum brake, it would have been a very good thing on Mr. Adams' part if he had shown how the brake would have acted, especially if it were applied in an ordinary case. As Mr. Jones remarked, the question of leakage could be taken as being much about the same. Mr. Selfe stated in his paper that the brakes were known to leak after being in use for three months.

Mr. Selfe: That is one brake—a single brake.

Mr. Kerle continued: Well, that might apply in both instances. If a train were descending a long grade, and the Vacuum brake were applied at the top of the hill, the brake would be graduated more or less as required; but in the event of the packing rings being out of order in any way, as there was more or less of atmospheric pressure on the under side of the piston—the reservoir on the top side being in vacuum—there would be a leak. Now if this leak was of a serious nature we should lose the vacuum on the top side, and the brake would be useless. The speaker then proceeded to deal with the stopping of trains with the different brakes, and said the time the Hanscom brake took to pull up was about three times longer than the Westinghouse brake, and therefore it was very much inferior in that respect.

He also said that there was nothing in the Hanscom brake or in the Vacuum brake to disconnect it in the case of anything going wrong. For instance, in the event of one of the joints breaking between the train pipe and the cylinder there was no cock of any description with which to disconnect the cylinder from the whole of the train. The result was that the whole of the brakes were rendered inoperative. These things were absolutely necessary, because, in the event of a slight accident or a leak being found in any of the cylinders, it would be necessary to disconnect one of those sets of brakes. They did not want to disconnect the train, especially if it were going down the side of a mountain. Again, in speaking of the Westinghouse brake, as regarded the triple valve, which was considered to be a very complicated matter, he thought they should look to results. They had seen the reports of the Board of Trade—which were doubtless authentic—and by reading those returns members could actually see what occurred. He had examined the triple valve, and he did not think there was much in it to get out of gear. It might possibly get out of order when fitted on a train, but then it would only be one of the valves, and of course not the whole of them. If a train was improperly fitted with brakes, then an accident might be expected, and it would occur with anything. In speaking of the Vacuum brake, there was another matter to be taken into consideration—that was the excessive waste of steam, as at the time when a person wished to apply the whole of his steam he must use his ejector to take his brakes off. That was a great defect. He concluded by saying that it should be proved conclusively, by open trials, which was the best brake for passenger and for goods traffic. It was far better to have open trials, and let the public have the best brake, than to have them mixed up.

Mr. J. Laing then rose to ask the President if he would give his statement respecting the trials of the Westinghouse brake, as he knew the members of the Association wished to hear it.

The President said he was quite prepared to give the statement. He also informed the members that the remarks in the paper he would read simply included the opinion of Mr. Pollock

and himself; the gentlemen present could take them for what they were worth. He then read the following paper:—

PARTICULARS OF TRIALS OF THE WESTINGHOUSE BRAKE,

Conducted in the presence of Mr. Robert Pollock and myself, on Saturday, the 3rd of September, 1887.

The train consisted of engine, tender, and seven carriages. Five of the carriages were fitted with the Westinghouse brake, also the tender; the other two cars being added to make up the required weight.

WEIGHT OF TRAIN.

	Tons.	Cwts.	Qrs.
Engine and Tender	59	5	2
No. 40 Carriage	16	10	0
„ 63 „	16	10	0
„ 65 „	16	10	0
„ 191 „	16	14	0
„ 10 „	6	10	0
„ 99 „	16	8	1
„ 117 „	16	2	0
	164	9	3
Total weight of train	164	9	3

SIZE OF SMALL RESERVOIRS.

No. of Carriage.	Description.	Length in Inches.	Dia. in Inches.	Contents in Cubic Inches.
191	2nd Class A type	22½	11½	2337
40	1st Class A type	29½	11½	3064
65	Compo. A type	29½	11½	3064
63	1st Class A type	22½	11½	2337
10	Compo. 4-wheeled	20½	9½	1453

SIZE OF BRAKE CYLINDERS.

All 10 in. diameter and 12 in. stroke except No. 10, which was 8 in. diameter and 12 in. stroke.

STROKE OF BRAKE PISTONS.

No.	40	had a Stroke of	7½	Inches.
,,	63	,, ,,	7¼	,,
,,	65	,, ,,	7¼	,,
,,	191	,, ,,	6¼	,,
,,	10	,, ,,	7	,,

5) 35.25 inches.

7.05 inches.

MEAN STROKE 7.05 INCHES.

In one of the Carriages were fitted four (4) gauges, the pipes being connected as follows :—

One to Main Reservoir.
,, ,, Brake Pipe.
,, Small Reservoir.
,, Brake Cylinder.

There was also an indicator and pressure guage connected to small reservoir, which very clearly recorded the variations of pressure in reservoir, the number of applications of the brake, also the time during which it was applied. On the engine, or rather on the tender, were two gauges—one from small reservoir end, one from brake pipe.

Mr. Pollock was on the engine, and noted all the necessary particulars relating to the steam pressure in boiler, speed of donkey pump, pressure on air guages, etc., while I remained on carriage watching the variations of pressure, etc., on the respective guages. I may mention that the size of donkey pump is—steam cylinder, 6 in. dia. and 9 in. stroke ; air cylinder, 6½ in. and 9 in.

The train left Redfern about 9.45 a.m., and went as far as Thornleigh, where all the trials were made. The grade was about 1 in 45, and the average time of each trial was from three to four minutes, and the distance run from two to three miles.

FIRST TRIAL

Pressure in main reservoir	... ...	80 lbs.	per square inch.
,, main brake pipe	... ...	70 lbs.	,, ,,
,, small reservoir	... ...	70 lbs.	,, ,,
,, brake cylinder	... ...	0 lbs.	,, ,,
,, indicator gauge	... ...	76 lbs.	,, ,,

Time of trial, three minutes—approximately ; thirteen applica-

tions of the brake; donkey going full speed (about 60 revs.); 133 lbs. steam on locomotive guage; brake piston pressure ranged from zero to 36 lbs., while the pressure in the small reservoirs was reduced from 70 lbs. to 5 lbs.; the pressure in the main reservoir remained almost constant, the first application bringing it down to 70 lbs., but afterwards it went up, and remained quite steady at 75 lbs.; so that when all the small reservoirs were practically exhausted there was a pressure of 75 lbs. in the main reservoir.

SECOND TRIAL.

This trial was very similar to the first, but perhaps it may be desirable to state the exact conditions.

Pressure in	main reservoir	... ...	87 lbs.	per square inch.
,,	main brake pipe	... ...	70 lbs.	,, ,,
,,	small reservoir	... ...	70 lbs.	,, ,,
,,	brake cylinder	... ...	0 lbs.	,, ,,
,,	indicator gauge	... ...	70 lbs.	,, ,,

Time of trial, three minutes fifteen seconds; then whistled for hand brakes, and forty-five seconds afterwards came to a dead stop. Total time, four minutes. Fifteen applications of the brake. No. 99 carriage taken off; donkey going half speed; 137 lbs. steam on locomotive gauge. During trial the pressure in the brake cylinder ranged from zero to 35 lbs. The pressure in small reservoirs was reduced from 70 lbs. to 5 lbs. in less than three minutes. The main reservoir pressure ranged from 87 lbs. at start to 50 lbs. at finish; that is, when the small reservoirs were practically empty the gauge on main reservoir showed a pressure of 50 lbs. per square inch.*

THIRD TRIAL.

Ran over the same ground, but under different conditions. In this case all the air brakes were disconnected, excepting on tender and one carriage cock shut behind, and the couplings disconnected, also all the other brakes off. Came down same grade in $2\frac{1}{2}$ minutes, and only used the air brake on tender

* NOTE.—The variation in main reservoir (87 to 50) was due to the fact of the donkey going half speed.

and one carriage until well down the incline, when the engine hand brake was used, which brought the train to a dead stop. The conditions were practically the same as in the other trials —80 lbs. in main reservoir at the start, 70 lbs. in small reservoirs. At the finish the pressure in small reservoirs was reduced to 25 lbs., while that in the main reservoir remained almost constant, never being below 75 lbs., donkey going full speed.

FOURTH TRIAL.—TRAIN STANDING.

Time taken to fill the five (5) small reservoirs with air at 70 lbs. pressure, the main reservoir being full and its gauge showing 73 lbs. at start and 71 lbs. at finish; donkey going full speed, and 137 lbs. of steam on locomotive gauges.

1st half-minute pressure rose to			...	35 lbs.
2nd	,,	,,	,,	... 48½ ,,

but it took four minutes to rise from 48½ to 68½ lbs.*

From the above it will be seen that about 50 lbs. per square inch can be forced into the reservoirs in 60 seconds, but after that the pressure rises very slowly.†

FIFTH TRIAL.—TRAIN STANDING.

Time taken to fill one small reservoir next tender, all the others shut off; donkey going full speed. Pressure in main reservoir 70 lbs.

1st half-minute pressure rose to			...	35 lbs.
2nd	,,	,,	,,	... 60 ,,
3rd	,,	,,	,,	... 67 ,,

SIXTH TRIAL.—TRAIN STANDING.

Main reservoir showing 80 lbs.; donkey going full speed; 139 lbs. of steam; thirteen applications of the brake; and in two (2) minutes all the three reservoirs were practically exhausted from 70 lbs. to 5 lbs.

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* NOTE.—All the small reservoirs were empty at the start.

† SPECIAL NOTE.—We cannot understand this, as with a constant pressure in main reservoir it should (except for the increased friction) fill five in the same time as it takes to fill one.

SEVENTH TRIAL.—(Under same conditions).

80 lbs. in main reservoir; exhausted all the air from small reservoirs in 1 min. 50 sec.; eleven applications of the brake. At the finish there was about 60 lbs. in main reservoir.

This concluded the trials.

What you have just heard is a fair and straight statement of what we actually saw, and although the time and figures may not be absolutely correct, we have no hesitation in vouching for their approximate accuracy.

It is also desirable to mention that the officers in charge of the experiments were willing and anxious to carry out all the practical suggestions which, in our opinion, tended to enhance the value of the tests.

At the conclusion of the trials we *felt anything but satisfied under certain conditions.* We had seen the air exhausted without difficulty. This was done in various ways, and in a very short space of time; but being of a practical turn of mind, and pleading guilty to having a large amount of mechanical scepticism in our composition, we wanted to know how and by what means this sudden exhaustion came about.

In answer to enquiries, the officers intimated their willingness to supply any information regarding sizes, proportions and capacities of the various parts of the Westinghouse brake, and also sent us a triple valve (in sections), which is now before you.

We are free to confess that before seeing this valve we had a very hazy idea of its action, and it was only after spending a considerable time in patiently studying its design and construction that we began to see and appreciate the rare ingenuity and admirable skill displayed, and which, as a mechanical appliance, is worthy of all praise.

In connection with this valve it is desirable to refer to Mr. Shellshear's remarks concerning it. He describes it as a very simple affair, so much so that, to use his own words, "any apprentice boy would have no difficulty in understanding it." Well, this may be so. We respectfully, but decidedly differ from him; in fact, we don't feel very sure of knowing all about it now; but

we have mastered it sufficiently to feel quite content to know that our want of perception and dulness of comprehension requires so much development.

Even Mr. Campbell himself never even hinted that the Westinghouse people ever claimed anything for its simplicity. On the contrary, he freely admits its complexity of parts; but what he did say was something like this, that although to those who do not understand or are prejudiced this triple valve may appear very complicated; it is so beautifully made, the proportion and construction of its parts so accurately arranged, that its liability to go wrong is reduced to the lowest possible minimum, and that, looking at its practical working, it is justly entitled to the public confidence.

We believe Mr. Campbell has fair justification in making that statement, and the fact that thousands of these valves are in daily use all over the world, doing good work, is very conclusive evidence of its truth. Mr. Campbell evidently looks upon the triple valve as an intimate relation of a clock or a watch, which, with all their complications, we put down as of no use unless they keep accurate time for years, and we expect them to do so without much examination or repairs. Speaking personally, I wish to say that, with respect to complications in mechanical appliances, I have received some wholesome lessons, and although I admire and appreciate simplicity in machinery as much as any man, still we should hesitate and make quite sure of our ground before we condemn any appliance because of the number of its parts. In proof of this let me point out that when the compound engine was introduced, a large percentage of engineers (myself included) raised the cry that the complexity of parts and the increase of pressure would, in the long run, cost more than could be gained by economy in coal, yet it has steadily made its way, and judging from what I see, there is little doubt that the triple and quadruple engines, with even more complications and much higher pressures, will do the same.

There are many gentlemen in the room who are connected with marine engineering, and they know as well as I do that our modern

machinery has reduced the cost of repairs in a very material degree. Not many years ago hundreds of mechanics were constantly and profitably employed in repairing the machinery of the numerous steamers trading to Sydney, but now such is the improvement in the soundness of design, the efficiency of construction, and the excellence of our tools, that, notwithstanding increased complications, the machinery runs from year's end to year's end at a fraction of the expense incurred in the old days, and although it may appear a strange thing to say, I have no hesitation in stating that it is the high degree of efficiency which has been reached in complicated machinery which has caused and is now causing such a depression in Sydney.

It was only the other day, when examining the machinery of one of the Orient steamers, the chief engineer informed me that the vessel had steamed from the old country to Sydney, and there was nothing required but what the engine-room staff could do themselves. This was with 160 lbs. of steam, and complications enough in all conscience.

This is a suggestive fact, and is mentioned to show that in examining or criticising any mechanical appliance, complication does not always justify condemnation.

Returning now to the triple valve, we find in it is contained the whole principle of the Westinghouse brake, and which, with your permission, I will try to explain in a simple manner.

Take our first trial. We started with 80 lbs. in the main reservoir, 70 lbs. in the brake pipe and small reservoirs, and in less than three minutes the whole of the small reservoirs were practically empty, although the pressure in main reservoir remained steady at 75 lbs.

Now here we have a train whose brake power has been purposely dissipated, and yet the driver of that train has practically the same pressure on his guage when the small reservoirs are empty as when they were full. He has plenty of power in his main reservoir, yet his brakes are useless.

To explain this we must go to the triple valve. Anyone looking at its construction and understanding its action must be

struck with the fact that it is not necessary to go on to a running train to be convinced that the air in small reservoirs can be exhausted without difficulty, for they have only to realise that the hole through which all the air must pass to charge or recharge the small reservoirs is so many times smaller than the passage for letting it out that it requires a very simple calculation to know how many full applications of the brake will practically exhaust them.

The size of the admission hole is equal to the area of a circle scarcely $\frac{1}{8}$-inch in diameter cut in two—that is, all the air has to pass through a semi-circular groove $\frac{1}{8}$-inch in diameter. The area of an $\frac{1}{8}$-inch circle is ·0121, and dividing this by 2 we have the actual area of the air passage, viz., ·0061. The diameter of the holes (smallest) from small reservoirs to brake cylinder is $\frac{5}{16}$-inch, the area of which is ·0769; then dividing area of hole through which the air passes to put the brakes on by the area of hole through which all the air has to pass to recharge small reservoirs we have ∵ $:\frac{0769}{0061} = 12{\cdot}57$, which tells us the hole from brake pipe to small reservoirs is $12\frac{1}{2}$ times smaller than the passage from the reservoirs to brake cylinder, and this is irrespective of friction, which in this case would vary approximately, as follows :—

Directly as the length of passage,
Directly as the square of the speed,
Directly as the density or weight, and
Inversely as the diameter.

Taking the Westinghouse book of instructions, we find, in pages 20 and 21, that "a reduction of 20 per cent. in the brake pipe pressure causes the triple valve pistons to move down and set the brakes at full force by means of the air in small reservoirs." And, again, "to set the brakes with full force takes an average of $1\frac{1}{4}$ seconds, and to open the release ports about the same time. To restore the pressure in small reservoirs requires from 15 to 30 seconds after a full application." This shows very conclusively that, taking the average time given—$15 + 30 = 45 \div 2 = 22{\cdot}5$ seconds—that it takes a great deal longer time to put the air into the reservoirs than to let it out; besides, it says nothing about any particular pressure that may be in the

reservoirs, and it certainly does not agree with the results we obtained on the 3rd September, where in the 4th trial, which was for the express purpose of finding what time it took to fill the five small reservoirs (they being empty at the start and train standing), we found it took one minute to get the pressure up to 50 lbs., but it took much longer to raise the pressure from 50 to 70 lbs. Going back to the small admission hole again; and remember that if they attempted to enlarge this hole the triple valve would be useless, in fact it would not work at all; because then the air in small reservoirs would come out so fast, and the pressure fall to such a degree as would certainly destroy the efficiency of the brake.

Assume a case, and suppose there is 70 lbs. in brake pipe and 70 lbs. in reservoirs, and we want to put the brakes on with full force, we, in accordance with instructions, reduce the brake pipe pressure 20 per cent., bringing it down to 54 lbs.; we have then 20 per cent. more pressure on top of triple valve piston than we have on the bottom; this acts on the piston and brings it down; but, remember, the air is *leaking past it all the time through the admission hole, but it can't get out quick enough to prevent the excess of pressure from acting, because it is so small.* When the piston has travelled $\frac{5}{16}$, the admission port is shut; it is then all right.

The size of the exhaust hole, or passage, is $\frac{3}{16}$-inch in diameter, and, comparing it with the admission hole, it is $4\frac{1}{2}$ times larger; its area is ·0276, and dividing the one by the other we have $:\frac{0276}{0061} = 4\frac{1}{2}$.

It may be urged that as all the air has to pass through the exhaust its diameter should be taken instead of the passage from reservoir to brake cylinder, but it should be remembered that the pressure is always much less in the brake cylinder than reservoir, that when released it has only to contend with the atmospheric pressure, and also that the exhaust port on the valve face is nearly twice as large as the exhaust passage, thereby allowing it to remain longer open, whereas the air from brake pipe has to be forced through a very small hole against whatever

pressure may be in reservoir, besides the immense friction to be overcome, and is all in favour of getting rid of your power much faster than it can be supplied.

GRADUATING THE PRESSURE.

This has been a much disputed point, and, without prejudice, am of opinion it can and is graduated every day. It is true the driver can't see the graduation, but there seems to me no difficulty in educating the hand to control any train. This means of graduating the brake pressure is a very clever contrivance, and appears to perform the same function for Westinghouse as the small injector does for the Vacuum brake, but it must not be forgotten that the Westinghouse can only be graduated one way—that is, when it is being applied to put the brakes on. There is no possibility of graduating the release, as every particle of air must be discharged into the atmosphere and the brakes taken completely off before another application of the brake is possible.

There is another point in connection with the Westinghouse which, I think, has escaped notice. It is this: Mr. Campbell, when speaking against the Vacuum brake, brought it prominently forward that the injector used a very large amount of steam.

No doubt it does; but let us look at the Westinghouse from an economical point of view, and see how it stands. For every full application of the brake you have to actually waste 20 per cent. of the brake pipe pressure, and taking their own figures, for a train of fifteen carriages you have to throw away 1,000 cubic inches of air, at a pressure of from 60 to 80 lbs., before the triple valve pistons can move their full stroke. Now this has to be done many hundred times every day, and as it takes a considerable amount of power to compress air to a high pressure, it appears to me that if the total quantity of air which is and must be wasted on applying the brakes was calculated, I feel pretty sure that the truth of a very old adage would be very fully realised, viz., "Those who live in glass houses should not throw stones."

Referring to Mr. Granlund's statement that the brake power on the New South Wales railways was only one half of what was fitted on the Victorian lines, and that for every 10 tons of brake

power here they had 20 tons. This, coming from such an authority, is no doubt correct; at the same time, let me direct your attention to No. 3 trial, where, in careful hands, the great efficiency of the Westinghouse brake was clearly demonstrated, for on that occasion a train weighing 164 tons came down a grade of 1 in 45 at a speed of over thirty miles an hour, the air being applied on the tender and one carriage only, the cock being shut off, and couplings being disconnected behind the first carriage.

This goes to show that although the brake power on the New South Wales lines may, in the opinion of some, be limited in amount, still there is, even in cases of emergency, quite sufficient left to control the train.

Looking at the Westinghouse brake as a whole, it appears to me that its weak point lies in the fact that, by careless handling and injudicious management, the stored power in small reservoirs may (under exceptional circumstances) be exhausted, which means that the driver may have a large quantity of power in his main reservoir, and yet the small reservoirs be practically empty, and on heavy down grades a little carelessness, inattention, and want of judgment may result in his losing control of his train.

This, I think, might be remedied to some extent by fitting another pressure gauge on every tender, which would always give him a fair idea of the amount of power at his disposal for putting on the brakes.

On the other hand, this brake is, in careful hands, a safe and reliable contrivance, and until Mr. Selfe or somebody else shows us something very much better, it will continue to merit the public confidence.

Referring to the large amount of correspondence which has taken place in the public press in arguing about the relative merits of the brakes, one thing stands prominently forward, viz., the extreme difficulty of sinking personal interests when discussing this question, and many of the statements made are to be regretted.

Where the Westinghouse people made the mistake was in claiming too much for it. Like any other human machine, it has its good qualities and its faults, which may, and no doubt will be, improved.

Let us, therefore, hope that, as in this age of progression we cannot stand still, the present discussion may be the means of making railway brakes more economical and reliable than at the present time.

It was my intention to have said something about the relative merits of the Vacuum and Hanscom brakes, but time has compelled me to confine myself to the above.

Mr. Henry Davies said this discussion was appropriate to the intentions and designs of the Engineering Association. He also considered that the debate had been of considerable value to all, because the good as well as the bad points of many of the brakes had been indicated. The speaker then proceeded to refer to the sudden and uncomfortable stoppages which occurred on the suburban stations between Sydney and Parramatta, and said that many peeple complained of this, and said it was to be attributed to the action of the Westinghouse brake. Now he did not think the sudden stoppages were due to the action of this brake, but they were the result of other causes connected with the condition of portions of the rolling stock. He thought the defects complained of would be got rid of in time; it was not the fault of the Railway Department that they had not been got rid of before. He objected to this defect being attributed to the Westinghouse brake.

Mr. G. A. Key then made a brief reference to what he considered to be some of the faults of the Hanscom brake, after which Mr. R. B. Campbell read the following statement:—

"I regret that discussion on the cause of the late accident at Peate's Ferry has been forbidden, as circumstances connected with that disaster, undoubtedly form a large part of the paper now before us, and I think it would have been more satisfactory if this portion of Mr. Selfe's paper had been thoroughly gone into, but in deference to the opinion of our President, I will content myself with drawing your attention to this duplicate of the piping and tap, which was found closed after the accident. It will be seen, that from the manner in which this metallic connection of the hose pipe is made, it would be impossible for the overriding of the carriages, during telescoping to wipe this handle parallel with the pipe;

without at the same time destroying the hose connected, and as the particular hose and tap in question were both new, and were found perfectly uninjured, there can be no doubt but that it was closed before (and hence) the accident, and all the evidence I have heard and read, fully bears this out.

"Mr. Selfe, in introducing the Hanscom brake to us, has also pointed out many of its defects, thus forestalling criticism. I fully recognise and appreciate the advantage which the addition of a second line of piping gives, and it was used many years ago by Mr. Westinghouse, in some of the first installations of his brake. It can easily be applied again to the existing brake, without impairing any of its existing attributes, should our railway authorities deem it desirable.

"It is significant that to overcome the more obvious defects in the Hanscom brake, Mr. Selfe has improved it by adding pure and simple, a Westinghouse triple valve.

"On studying the mechanism required for railway brakes, two principles may be recognised—(first) that for automatic action the power must be stored on every vehicle on which it is to be used, and (second) for the most efficient action the power must be conveyed to the brake pistons, as quickly and consequently through as short a travel as possible. To obtain this second desideratum, a valve on the principle of the Westinghouse triple valve must be used, which Mr. Selfe appears to have very clearly recognised.

"A Westinghouse triple valve is also used with the Vacuum brake, in order to make it more efficient. It is placed in the guard's van, and by its action helps to apply the brake more rapidly, from which it may be reasoned, that if one was placed upon every carriage its action would be still further improved, but then it would be practically a Westinghouse brake.

"I regret that I was not present to hear Mr. Adams' remarks at our last meeting, but I have since read what appears to be a very full account of them, and with your permission I will address myself to some of the statements he has made.

"It is perhaps unnecessary either for Mr. Adams or myself to advise the members of this Association as to the source of the

data to which they will give credence; but inasmuch as he has not contradicted my statement respecting the failures of the Automatic Vacuum brake, taken from the Board of Trade returns, for the six months ending June, 1886, and which differs so widely from his own statements, set forth as being drawn from the same source; but in defence turns round and challenges the correctness of his own authorities. I think this sufficiently demonstrates that my warning respecting the statements of interested parties was not uncalled for. Personally, I do not attach much importance to the Board of Trade returns, because in several instances we have gentlemen reporting on their own inventions, and had Mr. Adams not introduced them I might have not done so either, but since our last meeting I have waded through all the Board of Trade returns I possess, and the following table is a story they tell of the working of the Westinghouse and Automatic Vacuum brakes."

Half-year ending.	WESTINGHOUSE.		VACUUM.	
	Average time of delays.	Average of delays to Stock fitted.	Average time of delays.	Average of delays to Stock fitted.
30th June, 1884	3·75 min.	1 in 45·4	5·7 min.	1 in 20·3
June, 1885	4·57 ,,	1 in 25·54	6·4 ,,	1 in 21·85
June, 1886	4·13 ,,	1 in 48	6·3 ,,	1 in 24
Dec. 1886	4·59 ,,	1 in 40	6·14 ,,	1 in 44

Average for 4 half-years, Westinghouse ...	Time, 4·26 minutes. Stock, 1 fault in 39·76.
,, ,, Vacuum	Time, 6·13 minutes. Stock, 1 fault in 27·7.

"This comparison is made from the working of the Vacuum brake on the Lancashire and Yorkshire, and London and South Western Railways, and the Westinghouse on the North Eastern, London, Brighton, and South Coast, Caledonian and North British Railways.

"To the railway man, anxious to get on with his journey, it is a matter of little consequence whether his delays are caused by burst hose pipes, or twisted rolling rings, it is the number and extent of his delays that is to him important, and these returns incontestably prove that the Automatic Vacuum brake is a far greater defaulter than the Westinghouse. It is to be remarked,

also, that while the great percentage of Westinghouse delays take place from the simple hose pipes, the Vacuum are chiefly from the more vital parts of the apparatus.

"Regarding Mr. Adams' claim for a similarity of principle between the Hanscom and Vacuum breaks, it will be remembered that, on the night this claim was made, it was made generally, now it is thinned down to the engines and tenders only, sixty-five per cent. of which are not fitted with the Vacuum brake at all, but only the apparatus to work the train brakes.

"My remark respecting the triple valve seems to have been misunderstood. What I said was that they would probably work better after being two years in use, than when new, and for this reason: these valves move as often in one year as the valves in the locomotive move in a day, and, as is well known, it is only after an amount of use that slide valves, pistons, and similar parts, get the surface which enables them to work best.

"I come now to the very remarkable diagram which was distributed at the last meeting, and even now I am in doubt whether it is only one of Mr. Adams' little jokes, or put forward in seriousness. The language is plain. "At the point marked H the brake cannot be applied with required pressure." I cannot imagine by what manner of calculation this result has been arrived at, but as a matter of fact, not fancy, this pressure, and a great deal more than this pressure, is being obtained daily, and for the last ten years, over similar grades on our mountain roads. To put the matter beyond a doubt, I have made the experiment suggested by the diagram, on the apparatus erected by us in Messrs. Morris Bros. yard, in Wattle Street, in the presence of Messrs. Key, Kidd, Christy, Kendall, and others, members of this Association, and taking all the chances against ourselves, the result invariably was that we had the same pressure at the bottom as at the top. So much for Mr. Adams' diagram in connection with the Westinghouse brake. Let us now consider how his own brake would work over his own diagram. And we will first supply one or two necessary figures which have been omitted.

"Let us suppose the grades to be one mile long each, the speed thirty miles an hour. Now, according to all authorities, the problem of controlling a train, at a constant speed, requires that you should be able to supply a brake force sufficient, at the lowest co-efficient of friction, to cause a retardation equal to the force pulling onward. This co-efficient of friction, at thirty miles an hour, will be ·07, and taking the weight and brake leverage of our New South Wales ordinary bogie carriages, which are 16½ tons, and 5·77 to 1, respectively (which figures appear to me to be those which Mr. Adams has taken to calculate the required air pressure in the diagram), it follows that the pull of gravity on the first grade of 1 in 40, on this weight, will be 924 lbs., or one-fortieth of the weight. To supply a retardative force equal to this with a co-efficient of friction of ·07, will take ·07 × x = 924 lbs., or 13,200 lbs. of brake force. Let us see now, if the Vacuum brake, with same leverage, can supply this power. Assuming an initial vacuum of twenty inches, which, by the way, it will be difficult to get readily on our mountain tops, at 6-inch travel of piston, the power on the piston will be 7¼ lbs. per square inch. To be generous to an opponent, and certain in our results, I will give them 8 lbs. The diameter of piston is 18 inches, or 254·4 square inches in area, then 254·4 × 8 × 5·77 = brake force = 11,743 lbs., or (13,2000 − 11,743) 1,457 lbs. less than what is required under theoretical conditions, to control this weight over the first grade of 1 in 40, then if there be no hand brake power, the Vacuum brake will never control it.

"Mr. Selfe has told us of three grave defects in the Vacuum brake—(first) the power on the brake piston is not certain; (second) it is heavy and cumbersome; and (third) it is slow; and the only set-off to these defects is that it is 'gentle.' I trust that if any of you are in a railway train, and the question of stopping becomes a matter of salvation or destruction, you will have something better than a gentle, slow-acting brake to interpose in your behalf.

"The Vacuum brake has other deficiencies besides those enumerated by Mr. Selfe. First, or perhaps fourth, it is peculiarly

sensitive to leakage, and those who have any experience in the creation of a vacuum by means of an ejector will bear me out in that. As an instance : On one of the express trains, fitted with the Vacuum brake, running between Melbourne and Albury, the driver for two months could obtain no more than 15 inches of vacuum, though every effort was made to discover the cause of the loss. With the Westinghouse an incident of this kind would be impossible, and when taken into consideration with the next defect, it becomes very serious indeed. Fifth : A reduction of the initial or standard vacuum (as above) causes a much greater proportionate loss of power. For example : Should a driver not be able to get more than 10 inches of vacuum with 8-inch stroke of piston, and the present proportions of the carriage mechanism, no power whatever could be put on brake blocks, or, with 50 per cent. loss in the initial vacuum there is 100 per cent. loss in the power. Sixth : In the Vacuum no means are provided to prevent the brake being automatically applied when a train is intentionally broken up ; and our Assistant-Traffic Manager (Mr. Kirkaldy), speaking on this point, said that such a means is absolutely necessary and indispensable in railway working. Seventh : Should the mechanism go wrong on one carriage in the Vacuum system, that carriage and all behind it are incapacitated from being worked, and should this happen on the first carriage of a train coming down the mountains it might be very serious for the train. In the Westinghouse system, as is well-known, any defect on a vehicle may be limited to that vehicle.

" Generally considered, I think it will be admitted that, for the many purposes of a continuous and automatic brake, the Westinghouse is a more complete machine than either the Hanscom or Vacuum systems.

" Regarding the element of cost, which is so important to us now in our day of large deficits, Mr. Selfe has left the cost of the Hanscom brake to be estimated by the members, each man for himself ; but as in this class of mechanism a good part of the price is made up of patent royalty, for our complete information, he should tell us what Messrs. Hanscom and Selfe's royalty is likely to be.

"The cost of one set of Westinghouse and Vacuum mechanism is the same, but there is this difference, that for the money the Westinghouse supplys 48,000 inch pounds of force, while the Vacuum only supplys 20,624, so from this manner of comparison the Vacuum is over twice as costly as the Westinghouse, and it will be found in practice that this comparison stands good.

"The Vacuum brake consumes more steam, which means coals, which means money. The Vacuum Company have frequently tried to throw doubt upon this fact, but it is one that will not be denied, and a striking proof has just come to my notice. At the Exhibition in Adelaide, steam is supplied and charged for as consumed. The Vacuum Company have four sets of apparatus, similar to those at the Exhibition in Prince Alfred Park, their stand is in a corner, a little out of the way for sightseers. The Westinghouse Company exhibit fifteen sets of apparatus, with about 300 feet of piping. For two months' supply the Vacuum Company have been charged £9 12s., the Westinghouse Company, £4 17s.

"Again, the dead weight of the Vacuum mechanism is much greater than the Westinghouse, and in this country, where the carrying capacity is so much diminished by the heavy gradients, it would be very bad policy indeed to carry unnecessary dead weight on the bottom of our waggons, instead of profitable merchandise inside."

Mr. Adams handed in the following statement, having reference to the recently published returns by the Board of Trade upon the subject of brakes.

"Mr. Campbell has chosen to select from the English railways using the Westinghouse brake, two only, viz., the London, Brighton, and South Coast, and the North Eastern, and these, together with two Scotch railways, he compares with the Lancashire and Yorkshire, and the London and South Western railways, using the Automatic Vacuum brake. Now, although such a comparison may suit Mr Campbell, I think I shall be able to show you that, from a scientific point of view, it carries no weight whatever. In the first place railway companies vary considerably in what

they consider should come under the term fault. Some companies state the length of the delay, others do not mention it. Some return faults to both the patented parts and the ordinary brake rigging, others do not. Some return under the heading, "neglect of servants," a fault against the brake, others do not. Mr. Campbell has chosen just those railways that suit his own purpose. As Sir Henry Tyler, one of the directors of the Westinghouse Brake Company, recently said at a discussion on brakes, when the figures brought forward did not suit him, "Nothing was more easily distorted than facts, except figures," and having quoted Mr. Campbell's director in my favour, I will, with your permission, call your attention to a few facts, drawn from the Board of Trade Returns, for the year 1886. I find there that, in the half-year ending June 30th the Westinghouse brake ran an average of 125,000 miles to 1 fault on the London, Brighton, and South Coast Railway, but on the London, Chatham and Dover they only ran 7,000 miles to 1 fault,—what does this mean? Is there any difference in the design of the Westinghouse brake on these two railways? None, whatever; and yet we find this brake failing on the London, Chatham and Dover Railway 18 times oftener than on the London, Brighton and South Coast Railway.

"Now, let us take two similar cases with the Automatic Vacuum brake. On the Belfast and Northern Counties Railway we find that this brake runs 223,000 miles to 1 fault, whereas on the Glasgow and South Western a mileage of only 11,000 miles per fault is attained. Here we find this brake failing 20 times as often on the Glasgow and South Western Railway as on the Belfast and Northern Counties Railway. I think that this is sufficient to show the folly of picking out individual railways for the purpose of comparison, and applies equally to the Westinghouse as to the Automatic Vacuum.

"I have taken the trouble to analyse the whole of the returns for both half-years, and find as the result, that for the half-year ending June 30, 1886, the Westinghouse brake ran an average of 42,000 miles per fault, and the same for the Automatic Vacuum brake. But for the half-year ending December, 31, 1886, the

Blue Book reveals that the Westinghouse brake ran average of 38,000 miles per fault against the Automatic Vacuum brake 72,000 miles per fault, or an average in favour of the Vacuum of 2 to 1. But the Board of Trade Returns reveal practically everything against the Automatic Vacuum brake. With this brake no instructions are given to periodically examine, clean and lubricate the various parts. No such attention is necessary, and they go on working until worn out. With the Westinghouse brake, however, special instructions are given to examine, clean, and lubricate the various details, as, for instance, the triple-valves, pumps, driver's valves, governors, cylinders, etc., every three months; yet, in spite of all this, we have the numerous failures reported."

Mr. Selfe, in reply, said that he could not reply to the discussion that had taken place on his paper, and which had now extended over three nights without referring a great deal to the important places which the relative merits of the Westinghouse and Vacuum brake systems had occupied in the consideration given by members to the subject. Since he introduced the "Brake Question" to the Association, some of our members had been invited to see the Westinghouse brake worked on a train under special conditions, and the controversy which had been excited had no doubt induced the agents of the Company to erect the outfit for a train of ten carriages which had been on view at Ultimo, in order to give interested persons an opportunity of witnessing the actual working of their brake apparatus. He had here to acknowledge the courtesy of Messrs. Imray and Co. in sending him a special invitation to see it, which he availed himself of with much pleasure, although he proceeded to wreck the imaginary train at once, when he tried to handle it himself.

The most noticeable and important point in the whole discussion was the fact that the representatives of both the Westinghouse and Vacuum brakes, candidly admitted that in many important points the Hanscom brake was better than their own, and that was more than he could (as the introducer of Mr. Hanscom's invention to notice) have reasonably expected. He was prepared to admit, and would show presently, that in ONE feature the

Westinghouse brake had, for the present, an advantage, but as it was a feature that could be incorporated into the Hanscom system without infringing patent rights, he should, he thought, be able to bring the Hanscom out first of the three by a long way.

One or two members had evidently not quite understood the simple efficacy of the Hanscom brake enough to appreciate its merits fully, while admitting many of its good points; but Mr. Shellshear stood quite alone in his ideas of its practical value, and its cost. Unless he misunderstood that gentleman, he did not think it was automatic, but he did think a very dull apprentice would see that its cost must be 50 per cent. more than the Westinghouse per vehicle. He should, however, be able to show him if he had not already recanted, that there were in it only about one-third of the parts per vehicle (and those were of the most simple kind) that there were in comparison with those used in its great rival.

To come to the specific points raised during the discussion, it would be useless for him to reply to arguments taken *in globo* from trade circulars, or by extracts from the speeches of the Chairmen of brake companies, although such persons may have been Board of Trade officials at one time; because, however one-sided such arguments might be, they were often so specious, that it would take a book to refute them fully. But, he proposed to notice a few of the objections that had been taken to the Hanscom brake, and consider the special pleadings of the Westinghouse agents and engineer.

Mr. Adams, of the Vacuum brake, admitted the advantages of the Hanscom brake for working inclines, and in a very quiet way disposed of much of the pretentious claims of the Westinghouse representatives, but believed that he had an improvement that could be applied to his brake, and which he would be happy to show him, and that would make it much more instantaneous than it was now for emergent stoppages. Professor Warren showed conclusively that in the recent trials at Adelaide and Melbourne, the Vacuum brake, with all its simplicity, had in several ways the advantage over the Westinghouse, and he thought he admitted the

theoretical superiority of the Hanscom system to either. Mr. Campbell, of the Westinghouse Company, had spoken twice; first by courtesy and invitation, and (since his recent election) as a member. Mr. Campbell's first speech had been directed to show that from the Board of Trade returns, the Westinghouse was a better brake than the Vacuum, and that the Vacuum brake was not in use on so many lines as is represented. The second speech dealt with the reduction in the co-efficient of friction after the brakes had been applied, made some fun of the speaker's reference to the "gentle" application of the Hanscom brake, and went into a rhetorical rapsody about a train in the "inky blackness of night" dashing into a "Cootamundra chasm," after the bridge had gone, and further claimed that he had in his paper endorsed certain views adverse to the Westinghouse. He (Mr. Campbell) had produced at the same time a train-pipe cock and a length of hose and coupling, and had stated that the train-pipe cocks all had stops on them, to prevent the levers moving more than 90 degrees. So, he maintained that the cock (to the shutting of which his party attribute the late accident), could not have been shut by the telescoping of the carriages, but was never opened again when the train was recoupled. Now, he must, of course, give attention to a representative man like Mr. Campbell; more, indeed, than time would allow him to devote to any other parties to this discussion, and to take his points *seriatim*. From Mr. Hanscom's point of view, of course, he did not care a fig about the Board of Trade returns, because they had never yet had the privilege of dealing with the Hanscom brake. When they did so, there would certainly be fewer burst hose-pipes recorded against them than the Westinghouse now had, for the former's working air pressure was only about half that of the latter. The co-efficient of friction and its variation applied to all brakes alike, and he hardly understood why it was introduced at so much length, but this variation must be met much better in a brake like the Hanscom and Vacuum, that could graduate directly on and off, more or less, as desired, better than it could be done by an indirect acting brake with an intermediate regulator like a triple valve. The harrowing description given by

Mr. Campbell of a train going to destruction, and only a "gentle" brake to pull it up, was effective as a piece of bye-play, but was not relevant to the argument. If the action of a brake in bringing a train to rest in a given distance was represented by the train being caused to run up an incline to such a height as would consume the energy stored in the moving weight, then he maintained that a hollow or concave hill starting in a fair curve from the plane (as in the centrifugal railway) would, speaking comparatively, stop it gently, and that a convex hill rising abruptly from the plane to the same height in the same distance would bring it to rest in the same time, but with this difference—that while in the latter case, to say the least, the passengers would all be thrown out of their seats; whereas, in the gentle stoppage, equally sudden and effective, they would know nothing of what was going on. He wanted Mr. Campbell to understand that as long as the train was brought to a standstill in a given time and distance from the first application of the brakes, the apparatus that applied them directly, instantly, and gently, and then with gradually-increasing power up to the maximum, must be better, both for passengers and rolling-stock than the one that lets them on indirectly at second-hand, with a jerk, by means of a trigger, or triple-valve.

As regarded the shut-cock theory, he did not admit that he took any side in his paper, but was now forced to refer to it, because several government officials stated just now in reply to Mr. Campbell's assertion as to the stops on the cocks that *the cock on the wrecked train had no stops*, and that it *was supplied by the Westinghouse Company;* it was of course very curious to find out that during the inquest, the official enquiry, and in the reams of discussion that had appeared in *The Telegraph*, this point should not have been before settled. It was one certainty that had resulted from the discussion, and it confirmed the impression he had had all along, and that it was not necessary to believe that someone shut that cock the reverse way to the ordinary way when the carriage was uncoupled, and that he forgot to open it at all when the train was recoupled, to account for the accident or the cock being found shut afterwards, because the floor of that carriage went

twenty or thirty feet over the bed of the next one in the telescoping that took place, and the possible exhaustion of the air would render the brakes practically inoperative. The President's statements as to what he and Mr. Pollock actually witnessed confirm the Board's experiments and the opinions he had held from the day of the accident, and proved first that in a similar train to the one wrecked at Peat's Ferry the air could be exhausted from the small reservoirs in three minutes, and secondly that when the air was not exhausted, one carriage, the tender, and the engine hand-brakes would stop a similar train on that incline. He had been forced to refer thus to the accident at last by the action of the Westinghouse people, who should not have made him take sides in the accident question details, and should have been contented with their brake's undoubted merits, without claiming for it an infallibility that was a more suitable attribute of a simple machine like the Hanscom; and they should not have stated that he was championing the Vacuum brake when he did nothing of the kind.

Mr. Nelson had read from Reynold's work a long extract from somebody's paper in favour of the Westinghouse brake, and he summed up by saying—"It won't go wrong if it is worked fairly" now, talk about damning with faint praise, though that was a heavy fall for an advocate to give the brake.

Mr. Fischer remarked that he had not described the Herberlein brake, and gave some interesting information about it. He agreed with him, and he had had some particulars in his draft paper, but found it was extended too long, so he only referred generally to the chain-brake and similar systems.

Mr. Kerle had witnessed the agent working the Westinghouse brake, and had said no doubt the small reservoirs could be exhausted if unproperly used, and he admitted the Hanscom was better for working inclines. This gentleman had spoken of the flexible hose being responsible for 75 per cent. of the accidents recorded to the brake; but had forgotten that the Hanscom had a much lower pressure, and, therefore, less liability to burst hose. He (Mr. Kerle) was also wrong, he thought in referring to emergent stops being relatively so frequently required, on the whole he

had paid a good tribute to the advantages of Mr. Hanscom's invention.

Mr. Davies had defended the Westinghouse from being responsible for all the violent jerks attributed to iton our suburban lines, and to a large extent he was right; but it was not always the brake rigging and bogie frames which caused the disagreeable jerks referred to.

Mr. Key had taken exception to the friction of the piston-rod in the Hanscom brake; but as the Vacuum brake was successfully worked with less than half the pressure, there was nothing in that objection, the long-sleeved stuffing box being merely for a protector to keep the main packing clean and free from dust, and the friction need only be very little.

Having disposed of the criticism his paper had been subjected to, he might now say what he considered were the functions which a brake was called upon to perform, and that, in his opinion, its qualities should be considered under four separate heads, although in all the literature on the subject he had never yet seen them so separated. He recognised four separate and distinct duties that were required from a railway brake, the same special points or qualities *not being the first essential in all of them.* First, service stoppages; secondly, emergent stoppages; thirdly, automatic stoppages; fourthly, braking down inclines.

Now, what he recognised as the first essentials were:—In the first case, smoothness of application and release, and absence of sudden jerks and simultaneous application throughout the train.

In the second one, instantaneous application; in the third, certainty of action; in the fourth, the power of graduating the brakes on and off under the direct and positive control of the driver's lever.

It would be granted by all that the brake that would go full with the least reduction of train-pipe pressure should be the best to stop a train in an emergency; but if it was operated by a series of triggers in the shape of triple-valve pistons, which only came down when the variation of pressure overcame their friction in their cylinders at different times; and further, when the reduction of

pressure under them was insufficient, stuck up, and let the air out the same way that it went in; then, he maintained, such a brake should be the champion for jerking the passengers out of their seats, for dislocating vertebræ and for damaging rolling stock generally.

The very quality which made the Westinghouse brake good for emergent stoppages placed it last for service stops, as so much depended on the skill and judgment of the driver, who could, and generally did, handle it well. But while he put the Westinghouse brake first at present for emergent stoppages, it had to be remembered that for still more sudden stoppages than it was alone capable of, electro-magnetic attachments were indispensable; and as these could be applied to other systems equally well (as recently exemplified at Burlington, Iowa), this point was only of temporary importance.

With regard to the manipulation of the Westinghouse brake, the drivers had a book full of rules laid down for their guidance by the Westinghouse Company, and when they had thoroughly learned these rules and had long and careful practice, they could handle a train very smoothly and beautifully if nothing went wrong; but he would undertake to say that Mr. Shellshear's obtuse apprentice would learn to stop a train smoothly and effectively with a Hanscom brake in less time than he would require to understand what all the holes in a triple value were for. In the case of automatic stoppages he would grant that the three brakes were about equally effective, as one application only being required at a time, there was no advantage in an extra large service reservoir.

In the fourth quality, namely, that of being adapted to graduate trains down inclines, the Westinghouse brake, as used on the New South Wales lines, had been most conclusively shown to be the very worst possible, both in theory and practice. It had been shown by extracts from Mr. Marshall's Society of Arts paper that it was altered to non-automatic on the heavy grades of the rocky mountains in America; and one of the Westinghouse representatives here had told him that all the triple valves used in

America had a four-way cock. This cock enabled the train-pipe to be connected direct to the brake cylinder and cut out the triple valve altogether.

The argument that the Westinghouse brake was used every day on mountain inclines in the hands of skilful drivers only proved, that all being in perfect order and the man in charge being skilful and clear headed, the train would come down safely; but it was acknowledged by the agents and the drivers that all their care and skill was necessary to work effectively and with judgment.

It had, however, now been proved beyond the shadow of a doubt, that a train might be fitted so that the Westinghouse brake on the tender and one carriage, with the engine hand-brake, might control it on a heavy down grade by using great care, and yet in the same train, with much more break-power available on others of the carriages, a series of contingencies might lead to a driver so using up his store of air that the train might dash to destruction; and it therefore appeared to him that if the Westinghouse brake was to be retained on the passenger trains of this colony for the mountain lines, the members of this association must, by this time, have made up their minds that it was imperative that a second train-pipe and guage should at once be added to it. The fact that a driver could reduce his brake-pressure, but must take it off altogether and put it on afresh, was fatal to it; and the fact that he only knew by the effect on his train, and not by his gauges, what was taking place was another dark spot on its qualifications.

Under both the Hanscom and the Vacuum the graduation up or down was in the driver's hands, and in the Hanscom system there was the further advantage that having two gauges he knew exactly what was going on. With the valve he had introduced himself, it could be made as suddenly as required. Now what he had said might look very much like finding fault with the Westinghouse brake, but he would ask did it not arise from the fact that it had been devised for a service on comparatively level running, and had since been carried on to inclines and heavy gradients by

the wealth, influence and power of those who were interested in its use. He was thankful that the railways of this country were not run by wealthy capitalists or Jay Gould monopolists, and he believed the Government would give the public the opportunity of having the very best brake that could be found, or they would apply improvements to the one they had got, if it could be shown to be advantageous.

As regarded the quantity of air required for working the several brakes, he found, from some calculations made by Mr. Kiernan, and read before the Manchester Association of Engineers, 26th February, this year, that a Westinghouse cylinder 8 in. diameter and 6 in. stroke and 60 lb. pressure, required 100 cubic in. air at atmospheric pressure; whereas, an 18 in. Vacuum cylinder and 6 in. stroke, with 10 lb. effective pressure, requires only 678 cubic in. at atmospheric pressure, so that about 50 per cent. more air was required to put the Westinghouse brake on. But in the Hanscom we ran with air pressure on both sides of our brake piston; we let it out of one side and put it on the other, getting your power with the minimum expenditure of air.

With regard to the air required to charge and release the brake on a train of ten carriages, with 400 ft. piping, on both the Vacuum and Westinghouse, Mr. Kiernan's figures gave—

To charge—Westinghouse, 190·932 cubic inches; Vacuum, 61·812.
To apply brakes full—Westinghouse, 20·031; Vacuum, 19·633.

The statements made by the President as to what took place when he and Mr. Pollock attended the trials made on a running train, and also Professor Warren's experiences of the trials at Adelaide and Melbourne, so bore out what he advanced in his paper on the non-suitability of the Westinghouse brake for working inclines, that although Mr. Campbell and Mr. Granlund had made a good stand for their company by quoting Board of Trade returns, and by showing how skillfully their delicate instruments might be handled after long practice, there had still not been a really tenable defence of the Westinghouse brake made at all, and, on its merits for mountain service, judgment must go against it

by default. It was, therefore, unnecessary to go into the clever features of double hose pipes, metallic hose pipes, the new triple-valve (with about twenty more parts), and other refinements of undoubted skill and merit which were connected with its operation, but which were quite foreign to the question of simple efficacy in braking a train down, say, Lapstone Hill. On the question of cost raised by Mr. Shellshear, when he had said he thought that the Hanscom brake would cost 50 per cent. more than the Westinghouse, he made the equipment of one carriage into a table as follows, not including bolts or screws :—

Westinghouse.	Pieces.	Hanscom.	Pieces.
Cylinder and covers	3	... ...	2
Piston and follower leather	6	... ...	3
Crosshead and springs	4	... ...	2
Release valve	5	... ...	—
Triple valve	15	... ...	—
Reservoir	1	... ...	—
Inch cocks	2	... ...	—
Half-inch cock	1	... ...	—
Train pipe	1	... ...	2
		Automatic valve	4
	—		—
	38		13

The price of one set for a van in London was put down by the Westinghouse Company at £20, and £22 for a Bogie carriage. He did not know what the extra cost of the new triple valve was, but where those things were made a Hanscom outfit could easily be produced for £10 per set, unless his thirty years of workshop practice much deceived him.

In conclusion, he considered he had proved that the Hanscom brake had all the qualities required for working our inclines, and running our freight and passenger trains, with the maximum of safety and efficacy and the minimum of cost, and liability to derangement; and after an almost unanimous expression of opinion in its favour, he felt recompensed for bringing Mr. Hanscom's simple and clever invention under our notice.

The President said that now the debate was closed, he thought every member of the Association would join him in according Mr. Selfe a hearty vote of thanks for his paper.

A vote of thanks was unanimously passed to Mr. Selfe, and a similar compliment was paid to the President for his communication regarding the trials with the Westinghouse brake carried out under his supervision.

The discussion on the paper occupied the evenings of 8th and 15th September.

8th September.

W. D. CRUICKSHANK, President, in the chair.

The following candidate was balloted for and duly elected as

MEMBER:

R. B. CAMPBELL.

Messrs. Hargraves and Finlayson were appointed to audit the Society's books, accounts, &c., for the past year.

Discussion on Mr. N. Selfe's paper, on Railway Brakes.

ELECTRIC LIGHTING.

By T. Stewart.

Being Abstract of Paper read on January 19th, 1887.

A few months ago, when the author accepted the invitation of the Council of this Association to read a paper on the application of electricity to lighting purposes, it never occurred to him how difficult would be the task to deliver an interesting paper on so special a subject, or a paper that would be of value to an Engineering Association.

The paper is divided into several parts :—

1st. An explanation of the principles involved in the production of electrical energy, and its conversion into heat and light.

2nd. A description of the apparatus used for the generating the current for the light.

3rd. A description of the lamps used, their regulators, and also the manufacture of same, together with other appurtenances, such as leads, safety plugs, etc. ; also,

4th. A reference to the cost of the light and its advantages.

Electricity exists in two distinct forms, the static and dynamic, but the word " static " is somewhat misleading, because electricity, like heat, is now recognised to be a form of matter in motion.

Electrical potential, or that which produces an electrical current—just as a head of water produces a water current—is measured in units called Volts. One Daniell's cell produces 1·1 volts.

All substances resist the passage of an electrical current. The unit of this resistance is called an " Ohm." The ohm is the resistance of a column of mercury of a square millimètre cross

section, and 106 centimètres in length, at the temperature of melting ice.

The ampère is the unit of current, which is produced by an electro-motive force of one volt through a resistance of one ohm.

In all systems of artificial lighting, of whatever kind, the light is produced by the incandescence or glowing of solid particles of matter, and the heat required to produce this is produced in different ways. Ordinary coal gas consists of a combustible gas richly charged with very small particles of solid carbon, which being made white hot by the combustion of the gas, glow and produce the light required.

If these solid particles are removed the combustion of the gas produces no light. It will therefore be seen that to produce a light we must heat a solid body to incandescence.

To produce a given light with the smallest possible expenditure of heat—that is of fuel and cost—the heat must be concentrated on a solid body of the smallest possible size, so that, that may be raised to the highest possible temperature.

There is a class of substances called *conductors*, along which a current of electricity can be made to pass. Substances along which the current will not flow are called *insulators*.

No substance is perfect, either way; the best conductors offer some resistance to the currents, and the best insulators allow a little electricity to pass through them.

Conductors differ greatly in the facility with which they conduct electricity.

A platinum wire offers between five and six times the resistance to the flow of electricity as a copper wire of the same length and diameter, and the resistance of a given length of a given wire is greater when the wire is thinner, being inversely proportional to its cross section. With the same cross section it is directly proportional to the length.

Let it now be supposed that by means of a steam engine turning an electric generator a current of electricity is being forced through a long copper wire of large diameter, the only force opposing the flow will be the resistance of the wire. To overcome

this a certain quantity of heat has to be expended in the steam engine working the electric generator, and by the resistance the wire will be more or less heated.

The relative amounts of work expended and heat produced in sending a current through a thick and a thin wire of the same length and material are inversely proportional to the cross sections of the wires.

As long as the wire is of the same diameter and of the same material throughout, the resistance will be the same in all parts, and the heating will be uniform all along the wire. If, however, the copper wire is divided at one place and a spiral of very fine platinum wire is interposed, a great deal of resistance will be concentrated at one spot, and instead of the heating being uniform all along the wire, by far the greater portion of the total heating will take place in the spiral. See figure A.

Thus this arrangement of the electric current provides a means of taking heat from the engine fire and conveying it to any one place, at a distance, viz., the place where the spiral has been put.

It will therefore be seen that, when at the place where it is desired to concentrate the heat, a body of sufficiently high resistance is fixed, and a sufficiently strong current is passed through it, it can be made so hot that it will glow and give light.

This is the principle of all electric lamps, of whatever kind.

As to the generators of electricity, there are many kinds of batteries used, and for such instruments as electric bells or telephones the Leclanche battery is the most suitable. The batteries, however, do not maintain a current of constant strength, which is essential for the production of electric light.

The Bunsen, Daniells, and Bichromate batteries are also generally used.

The method of producing electricity by means of the battery is too expensive to be largely used for supplying the electric light, though useful in exceptional circumstances and for experimental purposes. To afford illumination on a practical scale the plan of converting mechanical into electrical energy, by the machines

termed magneto-electric or dynamo-electric generators, has been adopted.

In order that the principle of the action of these machines or generators may be understood, it is necessary to trace the connection between what are called magnets, and conductors conveying electric currents.

Lodestone or magnetic oxide of iron is found in a natural state in many parts of the world. A bar of this material has the property of attracting iron and steel, and when suspended in a suitable manner, of placing itself north and south, and is called a *natural magnet.*

A piece of hardened steel, rubbed with lodestone, permanently acquires similar properties, and is called an *artificial magnet.* A piece of soft iron whilst held under the attractive influence of a natural or artificial magnet is found to acquire *temporarily* magnetic properties, which vanish when the iron is removed from the influence of the magnet, This phenomena is called "*magnetic*" *induction.*"

The attractive power of a magnet is not eqally distributed throughout its bulk, but is found to be much more intense at some points than at others.

In a magnet in the form of a straight bar, the greatest attractive power is found to be located at two points at short distances from the ends. A bar magnet dipped into iron filings will be found to attract large quantities at its ends, leaving the centre bare. See figure B.

The end of a magnet which points to the north, it is well known, is called the north seeking pole, and that which points to the south, the south seeking pole. For certain experiments a compass needle is a very convenient form of magnet. If the north seeking pole of a magnet is brought near the north seeking end of the needle, it will be repelled, and the south seeking end attracted. In other words, like poles repel and unlike poles attract each other.

The attractive power of a magnet is greatest close to its ends, and falls off rapidly as the distance from the poles is increased.

For example, a magnet will attract any magnetic object one inch distant with four times the power exerted at two inches, or nine times that at three inches distance.

This will be well understood when it is known that the area round a magnet is pervaded by a magnetic influence, which is called the *magnetic field*, and the lines of force may be considered as running from one pole to the other in curved lines. See figure C.

The direction of these lines of force may be ascertained by placing a sheet of paper over an ordinary bar magnet and sprinkling it with iron filings, which will arrange themselves in curved lines, as shown in figure D.

These lines show the direction in which a small magnetic needle would place itself at any given point under the influence of the attracting and repelling forces of the magnet poles. It is convenient to consider the lines of force to flow from the north seeking pole to the south seeking pole, or in the same direction that a free north seeking pole would travel.

There is a limit to the size and strength of magnets formed by rubbing with a lodestone or permanent magnet, and therefore it has been found necessary to use another kind of magnet in the electric light generators, which is more powerful, although permanent magnets are still used in some machines.

A more suitable mode of imparting magnetic power is to pass a current of electricity through an insulated wire, wound round a piece of soft wrought iron. See figure E.

The iron will be converted into a magnet whilst the current is flowing, but will lose its magnetic power as soon as the current is taken off.

A magnet formed in this way is called an *electro magnet.*

The strength of an electro magnet depends on the number of turns of wire in the coil, and the strength of the current sent round it. A cylindrical coil of wire, through which a current is passed, itself becomes magnetic, and is called a solenoid.

A conductor conveying a current is surrounded by lines of force, just as a magnet is. The direction of these lines of force varies with the direction of the current. If a conductor is looked

along in the direction in which a current is flowing, the lines of force will flow round it in the same direction as that in which the hands of a watch revolve. As like magnetic poles repel and unlike poles attract each other, so will lines of force flowing in the same direction repel, and those flowing in opposite directions attract one another.

If a loop of stout wire be arranged to rotate upon its own axis between two magnetic poles, and a current be passed through it down one side and up the other side, it will be found to turn so as to place itself at right angles to a line joining the two magnet poles, and by means of a suitable apparatus for reversing the direction of the current at every half-revolution, a continuous rotation of the wire loop can be effected.

It has been shown how the mechanical rotation of a wire conductor can be produced by passing a current through it whilst in a magnetic field. The converse of this also holds good, that is to say, if a loop of wire is mechanically rotated in a magnetic field a current will be produced in it. If the wire loop is made to rotate between the magnetic poles N.S. in the same direction as the hands of a watch, a downward current will be produced in each side of the loop as it passes before the north pole, and an upward current when it passes before the south pole, the direction of the current being reversed at each revolution.

Whenever a conductor is moved near a magnet, so as to cut through lines of magnetic force, a current is generated (the effect is the same whether the conductor is made to approach the magnet, or the magnet the conductor). Currents produced in this manner are called *Induced Currents*.

It will be understood that to induce a current in a conductor it is only necessary to move it so as to cut through lines of magnetic force. The direction in which the current will be induced will be understood by imagining a person to be looking along horizontal lines of force in their positive direction, *i.e.*, north to south.

Then if a vertical conductor be moved from the left to the right hand of the person, so as to cut the lines of force, the induced

current in the conductor will be in an upward direction, and in a downward direction if the movement be from right to left. If the conductor be in the form of a ring, and is rotated on its axis at right angles to the direction of the lines of force; the current induced will be in an upward direction at one side of the ring, and in a downward direction on the other side—producing a continuous current round the ring. There is an important difference to be observed between the case of the lines of force of the current and that of the lines of force of the magnet. The lines of force of the magnet *are* the magnet so far as the magnetic forces are concerned, for a piece of soft iron laid along the lines of force thereby becomes a magnet, and remains so as long as the lines of force pass through it. But the lines of force crossing through a circuit are not the same thing as the current of electricity that flows round the circuit.

A loop of wire may be taken, and the poles of a magnet put on each side of it, so that the lines of force may pass through it from one face to the other; but if they are kept there for any period the presence of these lines of force would not create an electric current, even of the feeblest nature. There must be *motion* to induce a current of electricity to flow in a wire circuit.

When a coil of wire surrounds a soft, wrought iron core, a current can be induced in it each time a magnet is made to approach to or recede from the core. This result is due to the magnetism alternately developed and destroyed in the core. In the same way, if the magnet, surrounded by a coil of wire, is brought near an armature or piece of iron, its magnetism is affected, and a current is produced in the coil.

The very close connection that exists between magnets and conductors conveying electric currents, and the reversibility of their mutual action will be understood, and it is necessary to remember that to induce a current in a coil of wire by means of a magnet, there must be relative motion between coil and magnet. Approach of a magnet to a coil, or of a coil to a magnet, induces currents in the opposite direction to that induced by recession.

The stronger the magnet the stronger will be the induced currents in the coils.

The more rapid the motion the stronger will be the momentary current induced in the coils, but the time it lasts will of course be shorter.

The greater the number of turns in the coil the stronger will be the total current induced in it by the movement of the magnets.

By using a suitable collector or commutator, the currents, direct and inverse, can be sent through the external circuits in same direction.

All electric generators may be considered as machines for moving magnets past coils of wire, which coils may or may not have iron cores, or coils of wire past magnets, the connections being so arranged that the electro-motive forces generated may produce currents.

The motion is always circular, *i.e.*, the coils are attached to the rim of a wheel, so that as the wheel revolves they pass the magnets again and again. There are a number of dynamo machines of different forms, but they may all be placed under two heads, viz. :—

The "Alternating" type, where a number of coils are placed on the rim of one wheel, and a number of magnets on the rim of another concentric with it—one wheel being fixed, and the other is made to revolve. Alternating currents, or currents alternately in opposite directions, are produced in the coils, and are either used as alternating currents, or are converted into direct currents by being passed through a collector or commutator before being passed into the line.

The "Direct" type, where the wire is wound continuously round a ring of soft iron, the winding being as if the wire were wound spirally round a long iron bar, which was afterwards bent into the form a ring. In this type the ring revolves between two, or sometimes four or six, magnet poles, and although the currents are alternately in opposite directions in any portion of the wire, they are always in the same direction in the wires which are passing either pole. These currents are collected by the commutator

already referred to, and are passed as "direct" currents into the circuit.

There are two classes of generators. The magneto-electric, and dynamo-electric, In the first-mentioned machines permanent magnets are used; but in the latter electro-magnets with soft iron cores, excited by passing round them an electric current, produced either by the machine itself, or by a smaller machine provided specially for the purpose called an *Exciter*.

Almost all the machines now used for electric lighting are constructed with electro magnets, with soft iron cores—the principal of which has already been explained. The gramme machine of the direct type consists of a ring of soft iron, round which wire is wound as a continuous spiral forming a closed circuit. See Figure F.

It revolves between two poles of opposite names, the lines of force from which terminate in the ring. See Figure G.

As the ring or armature, as it is called, revolves, these lines of force are cut by the moving wires, and electro motive forces are generated in two halves of the ring, *in opposite directions*, so that they meet and oppose each other at the neutral points, N.P. See Figure H.

As long as no connections are made, no current is generated. If, however, the points N.P. are connected through an external circuit, such as a number of lamps, the two halves of the ring will act like two batteries in parallel circuit, and a current will flow through. See Figure I.

The ring being in motion, a permanent connection between the line and the wire in the ring cannot be made; but this is provided for by the collector, which is made of insulating material, often wood, and on which are a number of insulated metal strips. Each of these is connected by a wire to the part of the spiral wire opposite it, and two metal brushes press or rub on these strips at the points N.P. where the opposite electro motive forces diverge and join again. These brushes convey the current to the lamps. See Figure J.

There are three forms in which direct current machines are constructed to excite their own magnets. Series, shunt, and compound wound.

In the series wound machines, the magnets are wound with a comparatively short length of wire, thick enough to carry the whole current generated, and are connected in series with the armature and brushes. This dynamo must be excited by another machine or battery when first used. When the magnets have been excited a *residual magnetism* will remain in them, and this slight magnetism developes a feeble current in the armature ring. This current strengthens the magnets, and they in turn strengthen the current in the armature. These alternate currents or reactions continue until the maximum current the machine can supply is generated, which varies from one or two seconds with small machines, to about three minutes in large machines. The practical current that can be taken out of a machine is limited by the capacity of the wire to carry it without undue heating ; and the maximum is limited, first by the external resistance, or, if the machine be short-circuited, it is limited by the magnets approaching their saturation point, and by the internal resistance of the armature.

In shunt wound machines the magnets are wound with a large quantity of thin wire, which is connected with the armature brushes *in quantity* with the lamps or other external circuit. The currents in the magnets and lamps then divide according to the ordinary rules of divided circuits.

In compound machines the magnets are wound partly shunt and partly series.

A shunt wound machine cannot be short circuited without stopping the current as it is all removed from the magnets.

Armatures and comutators of the different types of machines are of various patterns, and the magnets are placed in very many different positions by each inventor.

Ring armatures, in which a large number of coils of wire are wound round a ring.

Drum armatures are wound lengthways over a drum or spindle, the wire being laid parallel to its axis.

Pole armatures in which the rotating coils are wound upon radial bars of iron, as upon the arms of electro-magnets—something like a spur wheel. The coils are almost without exception made to rotate, being lighter than the magnets.

Commutators.—To send the current from the generator into the wires as a continuous supply, a special device is employed, called a commutator, which, in the earliest form of generator, consisted of a piece of copper or brass tube slit longitudinally into two portions and fixed upon the axis of revolution so as to revolve with it, the two halves being fixed on a cylinder of insulating material, one of the halves being connected with one end of the wire of the coil and the other half with the other end, and against the tube pressed two contact springs or brushes to conduct the currents away. (See figure K.) The induced currents in the coils flow towards the commutator in the upper half of the revolution, and from the commutator in the lower half; then each half of the split tube, will, as it passes over the top of the axis, deliver to the upper contact spring, or brush, the current flowing into it, while the lower brush will always be feeding the return currents back into the lower half of the commutator. Of course in modern generators there are a number of coils in the armature which are necessary to procure a steady and continuous flow of current, and these coils are so arranged that they shall be brought successively into operation, the current beginning in one coil before it has ceased in another, the aim being to always have some of the coils passing through the point of maximum efficiency thereby securing the best of results—a steady and continuous current. If the coil, as shown in figure L, is revolved between the poles S an N—as it rises and revolves the number of lines of force that pass through the coil increases until it reaches 1, where the maximum number passes through—the current generated being inverse. After passing this point the number of lines of force decrease, and a direct current is induced in the coil until it arrives at 2, where the maximum is reached. From 1 to 2 will be a direct current in the coil, 2 to 1 an inverse current, the line 1—2 marking the boundary between the direct and inverse currents, and which is known as the diameter of commutation—1 and 2 being the contact points of the commutator brushes which convey the current to the main circuit for distribution to the lamps. The bars of the commutator are so arranged that one does not cease

to touch the brushes until the next has come up to contact, and there being no break in the continuity, the current is practically continuous.

In the former part of this paper it was stated that the heat produced by the electric current was conveyed through conductors and passed through the smallest possible space, so as to raise the temperature and cause light. According to the nature of the conductor passed through and made luminous by the current three large classes of practical means of producing electric light may be formed :—

1. Rarefied Air.—Made luminous by the passage of a current.
2. Voltaic Arc.—Formed by the passage of a current in air raised to a high temperature. This air heats the carbons or other bodies employed, by direct contact, and renders them incandescent.
3. Incandesence.—Solid matter, generally carbon, raised directly to a high temperature by the passage of a current.

The first named has not been practically applied ; the second, commonly called the " Arc," and the third the " Incandescent," are the sources of electric illumination.

The arc lamp is the most powerful. The principle on which it is worked may be described as follows. If a conductor along which electricity is passing is cut in two, and the ends are slightly separated, the current will cross the space so formed. The break, however, offers great resistance to the passage of the current, and intense heat is produced (the heat generated in any portion of a circuit being always proportional to the resistance of that part), Supposing, then, that a rod of carbon is placed to form part of a circuit, and whilst the current is flowing through the carbon be broken in two, and its ends be drawn a very short distance apart, a luminous arc of great brilliancy, called the Voltaic Arc (after Alexander Volta, F.R.S., Italian Professor), will be formed at the break. A small quantity of the carbon being volatilised, the light

is caused, partly by this intensely heated carbon vapour through which the current flows from one point to the other, and partly through the extremely high temperature of the carbon points themselves. The rods of carbon used in arc lamps are sometimes called electrodes, the upper carbon being usually the positive, and the lower the negative. In placing the positive carbon at the top the current is directed downwards, repels the rising gases, and the arc becomes shorter and narrower, compressed, concentrated, and consequently more intense. (See figure M.)

These carbons are acted upon by trains of wheels, and worked in guides by electro-magnets, forming part of the electrical circuit of the lamp, and thus a uniform light is obtained by keeping the carbons at the same distance apart as they burn away. There are many other modes of regulating or adjusting the carbons by springs, weights, and floats, etc. The current is sent through the two carbons, which touch each other end to end, and as soon as the current is established the carbons are separated slightly, and the current continues through the heated air, which is a partial conductor of high resistance.

Intense heat is produced at the ends, or poles, of the carbons, and particles of carbon become detached, and float in the heated air between, and form a luminous arc. The carbons being slowly consumed are actuated by the machinery before described, so as to keep the resistance as constant as possible. The arc light gives a much stronger light than the incandescent. The carbon, being thicker, can be raised to a higher temperature, the carbons used varying in diameter from $\frac{1}{8}$ inch to as large as $3\frac{1}{2}$ inches.

The temperature of the positive carbon ranges from 2000 to over 3000 degrees Centigrade, according to the size of the carbons, and it will perhaps be interesting to state that of all the artificial sources of heat the electric arc is the most intense.

The regulating electric lamps designed by "Brush" are a remarkable success. The feed is actuated by gravity alone, while it is controlled solely by the influence upon a bar of iron of a magnetic field, the intensity of which varies with the strength of the electric current passing through the lamp circuit. The lower

carbons are fixed, and as they burn away the upper carbons follow them, so the arc gardually descends, but for certain special installations, such as light-houses, or for purposes of projection, a focus-keeping arrangement has to be supplied. Like most of the modern electric lamps, the upper carbon descends by its own weight until it touches the lower carbon, and the circuit is thereby completed, the effect of this in the lamps is to cause a soft iron plunger to be drawn to a greater or less extent within a hollow coil, sometimes called a sucking magnet, and through the intervention of a lever and an annular clutch surrounding the rod of the upper carbon like a washer, the upper carbon is lifted away from the lower, and the arc is at once established. As the carbons burn away the arc has a tendency to become longer, and its resistance to increase, and this by reducing the strength of the current, diminishes the supporting power of the magnetic helix, allowing its plunger to descend, and in so doing to lower the carbon, and shorten the arc until the proper strength of the current is restored, when the rising of the plunger once more holds the carbon in position. So sensitive is the controlling apparatus to the smallest variation of current, that there is practically no reciprocating action such as this description might lead one to suppose, but the normal condition of the upper rod is to be slowly sliding through the clamp as the carbons become shorter; but if by any chance the rod slides a little too far, the clutch at once raises it again, and the carbons are adjusted to their proper distance.

Figure N gives an illustration of the principle by which the arc is controlled; X and Y represent the terminals of the lamp, which in this case consist of hooks, which, by being dropped over pins attached to the ceiling, and which are in connection with the line circuit, place the lamp in circuit with the machine. The current entering at X is transmitted through the two hollow bobbins, H and H^1, in parallel circuit, the out-coming ends being joined together and connected to the upper carbon holder, N. If the carbons are in contact the current flows through them and by the vertical rods of the lamp to the terminal hook, Y. The effect of this is to convert the two solenoids, H and H^1, into magnets, which,

by drawing into themselves the two iron plungers, N and S, lift one edge of the washer-clutch, W; this, by its oblique action, seizes the carbon rod (much in the same way as a tent-rope tightener grasps its cord), and lifts the upper carbon until its influence is balanced.

The carbon pencils consumed under the brush system are a foot long, and are electroplated with a thin covering of copper, which increases the life of the carbons; they last for eight hours, during which time about nine and a-half inches of the positive, and about four inches of the negative carbon are consumed. When the lamps are required for a longer period double carbon lamps are used, fitted with two pairs of carbon holders, and each is controlled in the same way as the single carbon lamp; the controlling apparatus, however, is not duplicated. When the lamp is started, the arc is formed between one of the pairs of carbons, and when they have burnt out the other pair automatically starts into action. The change from the one pair of carbons to the new ones is effected by a purely mechanical means, and by a contrivance which is extremely simple.

Figures O and P will show the action of this apparatus, and the washer clutch will be more plainly shown than in figure N.

C C is the hollow solenoid or sucking magnet, which exercises a magnetic influence upon the soft iron-plunger P. The rising or falling of this plunger raises or lowers the frame K by the lever L. R^1 and R^2 are carbon holders, which pass vertically through the casing of lamp. W^1 and W^2 are the clutch washers which surround them. One side of each of these washers passes between a pair of jaws, forming part of the frame K, and when the frame is drawn upwards it tilts the washers, and causes them to clutch the rod on diagonally opposite corners. One pair of jaws is slightly higher than the other, and it takes a grip before the other begins to act, and, therefore, lifts its corresponding carbon higher than its neighbour; the consequence is that only one arc is established; viz., across the lesser distance; and in all the subsequent feeding and controlling the pair of carbons first started are alone affected, because, although both carbons are raised and lowered

together, the lower end of the reserve carbon is always higher than the other by the difference in the height of the two pairs of jaws on the frame K. Owing to the shortening of the consuming carbons they can no longer meet when the frame is dropped, and the current by which they are again separated can only be transmitted by the reserve carbons coming into contact—the circuit is thereby completed, the new carbons are separated, and the arc between them continues to be controlled by the magnet and clutch in the same way as the first arc was.

The arc light is used almost entirely for outside lighting, being unsuited for interior illumination, which is better provided for by the "Incandescent" lamp, in which a filament or small wire of carbon placed in an air-tight globe, to protect it from the chemical action of the air, is raised to incandescence, by the passage of a current, and produces light for a very long time before it is destroyed. The length of time the filament lasts, or the life of the lamp is often more than 1000 hours of total lighting, in fact some of the best manufacturers guarantee an average life of 2000 hours. Woodhouse and Rawson's lamps have in some instances been in use for over 4000 hours, and the Edison lamps at the Theatre Royal, Manchester, have run 6000 hours. For a given temperature the durability of the filament depends on its uniformity, and on the completeness of the vacuum. Below a certain temperature, nearly corresponding to that of melting platinum, a well made filament in a good vacuum is very durable, and lamps will, under these conditions, last six or even twelve months of ordinary domestic work. The chief lamps now in use are the Swan, Edison, Maxim, Lane-Fox, Swinburne, and Brush Victoria, they differ principally in the shape and method of preparing the carbon filaments, and the manner in which the conducting wires are attached. (See figures Q^1.)

The carbons consist of some vegetable substance, which has been carbonized by heat. Metal filaments, usually platinum, have been tried, but without success, and carbon is now solely employed for the purpose, the materials being jute, bast, manilla, hemp, cane, bamboo, cotton-thread, bass-broom, fibre, card-board, etc. Figure, Q^1.)

The ends of the filaments are connected to two platinum wires, which pass through the glass, and are melted on to it. Platinum is used, as its expansion rate being about the same as glass, the latter does not crack in cooling, and it also joints well with the glass, which, of course, is a very important consideration, seeing that a good vacuum is required to be kept. (Platinum fuses at 2000 deg. C.; carbon has never yet been fused).

The Swan carbon filament incandescence lamp was first exhibited in 1869. Mr. Swan experimented for many years, his earliest form of lamp being a glass bell, having a horse-shoe of carbonized paper. [See figures Q 2.] The small arch of carbonized paper being about one inch high, and half inch across—the lower ends clamped to small blocks of carbon, the bell being exhausted as far as possible. This lamp had not a long life as the filament when the current was passed through it became hotter on the inner than the outer edge, and under this unequal influence began to curl over, bending until the crown of it came into contact with the glass, causing it to shatter. Paper havingbeen found unsuitable for filaments, Mr. Swan ultimately adopted cotton thread, which, when prepared by steeping in sulphuric acid and water until the tissue is destroyed, and then properly washed and dryed, produces a horny homogeneous filament of very considerable strength, the density and uniformity of which is increased by passing it between compressing rollers, which flatten it, so that a somewhat increased area of incandescent surface is obtained. This filament, which is made of a length and thickness proportioned to the current to be employed in heating it, is held in its position by the platinum conducting wires, which pass through the body of the glass globe, and are fastened to the ends by clips or sockets, and sealed in by fusion. It has been ascertained that if the glass-bulb be exhausted of air to a very high degree, the life of the lamp is prolonged. In order to get a good vacuum, Gimingham's vacuum exhauster, which is a simplification of Dr. Spengell's mercury vacuum pump, is used. Whilst exhaustion is being proceeded with, the carbon filament is raised to incandescence by passing a current through it of a higher degree than that ultimately required to be produced in using the

lamp. By passing this current through while the lamp is attached to the pump, all the gas is driven out of the carbon, and is removed by the pump, and the lamp is thereby rendered more durable, the wasting of the carbon, and the obscuration of the glass by the deposition of very minute particles of carbon on its surface is completely avoided. The lamp is sealed while the current is still passing. The Swan lamp is exhausted to the one-thousandth part of an atmosphere.

The process of manufacture of such lamps—*i.e.*, the manner in which the several parts are put together—is shewn in figures R. 1, 2, 3, 4, 5, 6. No 1 represents the filament which is attached to the platinum wires, and mounted on a glass bridge, little beads of glass being also formed on the wires where they are to pass through the walls of the lamp. The glass globe is blown as in figure 2, and with a file is cut into two pieces, as in figure 3. The carbon and platinum wires are inserted, and the latter fused on by the blow-pipe, as in figure 4. The portions of the globe are then joined together, and the lamp is complete, ready for attachment to the pump to be exhausted.

Holders for the lamps are made in a great many different forms. The one generally used consists of a block of boxwood, to which is fixed a spring wire with a ring which fits round the neck of the lamp, and two springs, one of which hooks into each of the platinum rings of the lamps. These contact springs are attached to little brass binding screws at the sides of the wood. It is important that both the contact wires should be springs, because if they are made in the form of simple hooks, they are liable to be displaced by vibration, and contact thereby becomes broken, and the lamp is extinguished. The conductors used for conveying the electric current from the generators to the lamps must be carefully proportioned to the work required of them, because, when electricity passes along a conductor it meets with a certain amount of resistance, which, as already stated in this paper, varies with the size of the wire, and the material of which it is made, and the conductor becomes more or less heated. When the diameter of the wire is small, the resistance to the passage of the electric

current is great, and the wire is heated. If the resistance is sufficiently great, the wire will become white hot, and may even be melted. Some metals offer less resistance to the electric current than others, and are therefore called better conductors. From the following table it will be seen that the high price of some of the metals named, and the want of ductility and strength of others restrict, within very narrow limits, the choice of metals to be employed as electric conductors. The conductivity of silver being taken as 100, we have :—

Metal.	Electrical Conductivity.	Heat Conductivity.
Silver	100	100
Copper	80	73
Gold	55	59
Zinc	27	—
Tin	17	23
Iron	14	14
Platinum	10·5	10
Lead	7·8	11
Antimony	4·3	—
Mercury	1·6	—
Bismuth	1·2	2

Silver, which is the best conductor, is too costly for any but exceptional use. Conductors are almost wholly made of copper, of iron, and of certain alloys, such as phosphor bronze, and silicium bronze. Copper is the metal most employed in applications of electricity. Coils of electrical instruments of all kinds are almost exclusively made of it, also the cores of subterranean and submarine cables. Electric light heads are made wholly of it, either as single wires, or in cables formed of several wires twisted together.

The difference of resistance offered by various metals to the passage of electricity can be illustrated by a simple experiment.

If a short piece of platinum wire be inserted between two lengths of silver wire of equal diameter, and a strong current passed through them the platinum wire will be heated to redness, whilst no alteration will be seen in the silver wires. This is because the platinum offers six times as much resistance as the silver wire

does to the flow of the current. The resistance offered by conductors to the passage of the current requires a certain amount of power to overcome it, and all power so expended represents a cost for which there is no return in light, and which is therefore, a certain waste which cannot be avoided. All wires, however thick, and of however good a conducting material, offer some resistance to the current, and, therefore, are to some extent heated; but with stout copper wire this is usually imperceptibly slight. The thin filaments of carbon used in incandescence lamps grow hot, because of the great resistance they offer to the current.

If the length of a wire is doubled its resistance is doubled. If the section is doubled the resistance is halved. If we double both length and section the resistance remains unaltered. As it is of the utmost importance that heat should not be developed in any part of the circuit, excepting the lamps, the conducting wires and the coils of the magneto apparatus that are employed to regulate the feed of the lamp, are made of stout copper wire, and the danger of fire is thereby reduced to a minimum; besides this the resistance of copper increases one-fifth per cent. for each degree, Fahrenheit, increase in temperature.

Carbon is a substance whose resistance diminishes as the temperature increases. It is not economical to use wire of a small diameter, except for very short leads, on account of the waste of power incurred in forcing the current through them, and in practice, therefore, it is not so much a question how small a conductor may be used without over-heating, but rather what size of wire will be most economical, having regard to the prime cost of the conductor, and to the annual cost of the motive power necessary to force the current through it.

All wires for conveying currents for electric lighting are well insulated, the larger wires are insulated in a number of ways, with gutta-percha, asbestos, nigrite, and with various other compounds, and are wound with tarred tape or other waterproof covering. They are sometimes enclosed in lead pipe. The finer wires are enveloped in silk or cotton.

There are two reasons for taking the greatest of care in insulating the wire conductors. First, that an electric current, especially of high tension, has the tendency to flow out at any points that give it an easy passage. A damp wall, for instance, offers a facility for leakage in conductors placed against it. The smallest contact with any moist object allowing it to escape.

The second reason is on account of the danger in leaving bare conductors within the reach of persons ignorant of the elementary characteristics of electricity. This, however, is a danger which is greatly exaggerated. Sir William Thomson has said that, there is more danger in a circular saw running at full speed in a mill, than in a dynamo-electric generator of high E. M. F. To guard against accident, however, the wires are all carefully insulated.

To prevent the wires being fused, through the current being increased, safety plugs or bridges are used which consist of easily fusible wire, composed of sixty parts of lead to forty of tin, of a thickness suitable for the probable strength of current that must be carried. If the current should by any means be increased the fusible wires are melted and the danger of the conductor being over-heated is obviated. These safety plugs are placed at points where the wires branch off from the main conductors.

The two principal methods of grouping lamps are respectively denominated, simple circuit, and compound circuit (see fig. S.) Lamps in simple circuit or in series, the current passes through from one to the other, and back to the generator, as shown by the arrows.

Lamps in compound circuit parallel arc, or multiple arc figure T) are placed as a bridge across the circuit from a main leading wire to a main return wire. This is the system adopted by Edison. Another arrangement of grouping, called "in derived circuit," "in derivation," sometimes called "in shunt circuit," is frequently adopted (figure U). The great advantage of this mode of grouping is that the failure of one lamp does not involve the extinction of the remainder, as there is still a path open for the current through the wire shunts.

Having explained the mode of producing the light, it will not perhaps be out of place to pass a few remarks as to its many advantages. An increasing amount of attention has been given to lighting by electricity, and there is a rapidly extending desire for more intimate knowledge of the laws which its phenomena involve. The subject has been treated in its scientific aspect, but its domestic side has been altogether overlooked, or I may say ignored.

There is one common fault with all forms of artificial light, and that is, they all, to a greater or lesser degree, consume the oxygen of the air. A perfect light, in the first instance, should not rob the air of its oxygen; it should not vitiate the air; there should be no danger from it; it should not be an unpleasant light, nor be difficult to control, and, above all things, it should not be expensive.

The following table shows the oxygen consumed, the carbonic acid produced, and the air vitiated by the combustion of certain bodies burnt so as to give the light of twelve standard sperm candles, each candle burning at the rate of 120 grains per hour :—

Burnt to give light of 12 candles.	Cubic feet of oxygen consumed.	Cubic feet of air consumed.	Cubic feet of carbonic acid produced.	Cubic feet of air vitiated.	Heat produced in lb. of water raised 10° F.
Common gas ...	5·45	17·25	3·21	348·25	278·6
Paraffin	6·81	34·05	4·50	484·05	361·9
Sperm candles	7·57	37·85	5·77	614·85	351·7
Wax do. ...	8·41	42·05	5·90	632·25	383·1
Stearine do. ...	8·82	44·10	6·25	669·10	374·7
Tallow do. ...	12·00	60·00	8·73	933·00	505·4
Electric Light...	None	None	None	None	13·8

It will be seen from this statement that the electric light is the nearest approach to the perfect light. The incandescent lamp is exhausted to such a high degree that there is almost a complete absence of oxygen, and, in fact, the light depends for its existence upon the absence of oxygen, which is exactly the reverse with all other forms of artificial light. If oxygen could be absorbed for only one second the carbon filament would be consumed, and the light would be extinguished. No air, therefore, is robbed from the rooms, nor are any noxious fumes thrown off. Ordinary gas is

very poor in carbon, so that a very large amount has to be consumed to produce the necessary light. The illuminative portion equals 10 per cent. of the whole, the remaining 90 per cent. produces heat and throws off moisture and carbonic acid gas from their combustion, which increases the temperature of the atmosphere, and of course vitiates it in a greater degree than candle or oil light.

As to the question of danger to life and of fire. Almost daily we hear of serious accidents through the use of gas, but little or no notice is taken of them. In England and America, where the electric light is very largely used, the slightest accident in connection therewith is fully commented upon, and in this colony we are initiating the same crusade. The dangers of the use of the light are greatly exaggerated. Of course there is danger with currents of very high tenison. Continuous currents of over 300 volts and alternating currents of over 200 volts are dangerous to human life, but with the perfectly insulated wires used for house lighting it is impossible to harm life or property. Besides this, a low E.M.F. is required for lighting the insides of houses, and the danger is reduced to a minimum. So far as the lamps are concerned, the incandescent is beyond doubt the very safest form of lamp. The majority of fires, for instance, are traceable to something connected with the lighting. A candle sets fire to drapings, curtains, etc.; a kerosene lamp is overturned; a gas bracket is brought too close to the wood or paper of partitions; or the light without a globe or any protector is allowed to burn too close to a ceiling, and it ignites the woodwork or canvas lining, and the whole place is in flames immediately.

With the incandescent light, in the first place, no match, the latent source of danger, is required to light it. Simple switches are used, by one turn of which the light is turned on or extinguished, and should a lamp—that is, the glass globe—be broken, the light is immediately extinguished. No explosions can occur, as with gas, and the electric current does not leak out and charge the air with poison. The incandescent light is a very pleasant one, and is not trying or injurious to the eyes. Of course, if one

gazes at the light, the eyes suffer in consequence; but this, it is well known, would occur with any strong light. Besides, it must not be overlooked that suitable globes to temper the light to any degree of brilliancy can be procured.

No scientific knowledge is required to control the electric light; switches are arranged for cutting out one or more lamps at a time, or lowering the light, as required, and the moment it is wanted it can be turned on; children can be trusted with it, and in cases of sickness it can be turned on at once. It is highly valued for large assembly rooms, ball rooms, and other places of meeting, which when lighted with gas, are perfect ovens; but when the electric light is used are perfectly cool, as the latter depends for existence on its non-combustion, instead of absorption of oxygen. It is completely free from deleterious products.

Professor Barratt, F.R.S.E., of the Royal College of Sciences, Dublin, comparing the different illuminating agents in use at the present moment, said, that for the same amount of light, gas cost 6d., the Glow, or incandescent electric light 6d., and the Arc 3d.

Parrafin oil occupied a very high position as an illuminant in cheapness and undeleterious nature of waste products, but its disagreeable smell, and the danger attending its use were against it. Electricity gave rise to no deleterious products at all, but the Arc lamp gave a dazzling though flickering light, throwing intense shadows. The Arc light was far less expensive than the Glow light. In calculating the cost of providing the electric light for a house, the chief item was the interest on the capital laid down in plant; the actual supply of electric energy was the least of the items. For two hundred lamps, lighted 500 hours a year, it was cheaper to have gas than the arc electric light, but in gas the chief cost was the consumption of gas, and when the number of hours a year in which the light burned was extended, the relative cost of the two systems was reversed. The great requisites for an artificial light were steadiness, accessibility, cheapness, safety, non-deleteriousness, and whiteness.

The Trinity House Committee, after very complete experiments in May and June, 1885, with illuminants for light-houses,

sum up their report with these conclusions as regards electric light :—"That the electric light as exhibited in the A[a] experimental tower at the South Foreland, has proved to be the most powerful light under all conditions of weather, and to have the greatest penetrative power in fog. That for the ordinary necessities of light-house illumination, mineral oil is the most suitable and economical illuminant, and that for salient headlands, important landfalls, and places where a very powerful light is required, electricity offers the greatest advantages."

To show the power of some lights now in use, it may be here stated that a 40,000 candle-power light on the Chicago Board of Trade tower, has been seen distinctly at Benton Harbour, Lake Michigan, 83 miles distant.

The question of the cost of production and supply of the electric light to houses is a most important one, and it depends on the conditions of the installation in the same way as the price of gas varies in the different localities, according to the quantity supplied and the facilities for manufacture.

No exact rule is laid down for calculating the cost of electric lighting generally, but when the conditions of any proposed installation are known, an exact estimate can be made.

Electric light on the arc system is less expensive than gas, and on the incandescent system, more costly.

The electric light is, as yet, little used in this colony, and it is therefore impossible to get a reliable estimate of the cost of its supply, as compared with gas. The Government has several large installations, but as these are of such a special nature and of an expensive form, to meet the requirements of the places at which the light has been adopted, it would not be fair to quote the cost as a standard for other istallations. The author is not at present prepared to go into figures, but might perhaps mention that the number of hours the light is used annually make a great difference,—for whilst the cost per hour of a gas-light remains constant whatever time it is kept burning, the cost per hour of the electric light decreases considerably as the number of hours it is used increases.

This is very easily understood when it is considered that the interest on the capital outlay and other charges remain the same whether the electric light plant is used for one or twelve hours, and that consequently the expense per hour will be materially reduced in proportion as the number of working hours are increased.

The quantity of gas required to produce a light equal to 1,000 standard candles (assuming the standard burner using five (5) feet per hour to give an illumination equal to 16 standard candles) would be 312 cubic feet, which, at 2s. 9d. per 1,000 feet, would cost in England 10½d. Certain companies in England propose to supply the light to the public in towns at ½d. per hour for each 20 C.P. lamp, or about 2s. per hour for a total light of 1,000 candles. For arc lighting large installations can be carried out as low as 3d. per hour per 1,000 candles.

At Denver, in Colorado, the streets are to be illuminated by electricity, at a cost of 28 dollars per lamp, against 35 dollars—the lowest offer of the gas company. There are 450 lamps, the system is the Edison, and the plant will cost 20,000 dollars; twenty circuits, 27 lamps to each circuit when each circuit has its full compliment; the lamps to be placed on the existing gaslight posts.

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LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

THE JETTY SYSTEM AS APPLIED TO THE RIVERS OF N.S.W.

Plate I

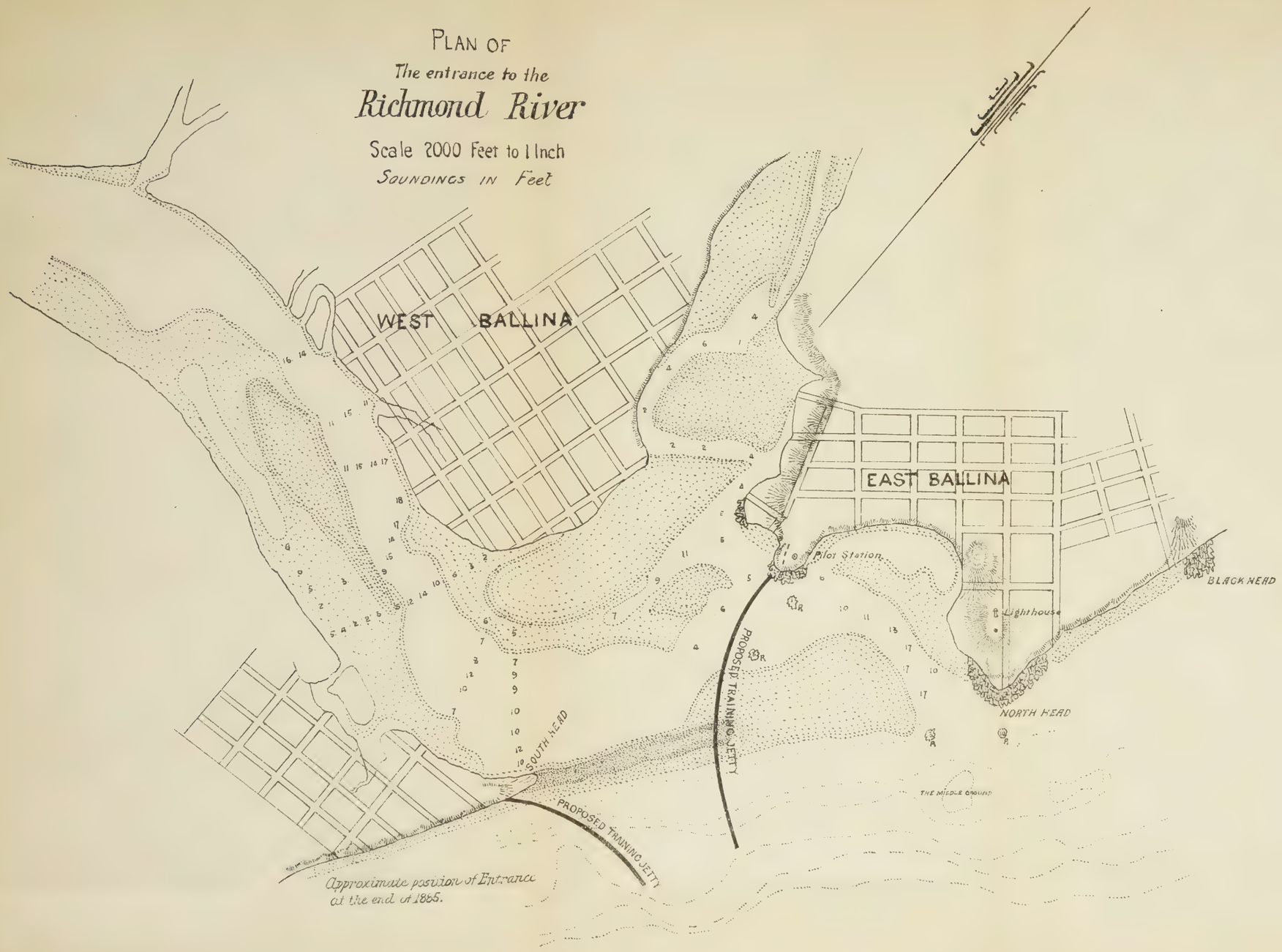
PLAN OF

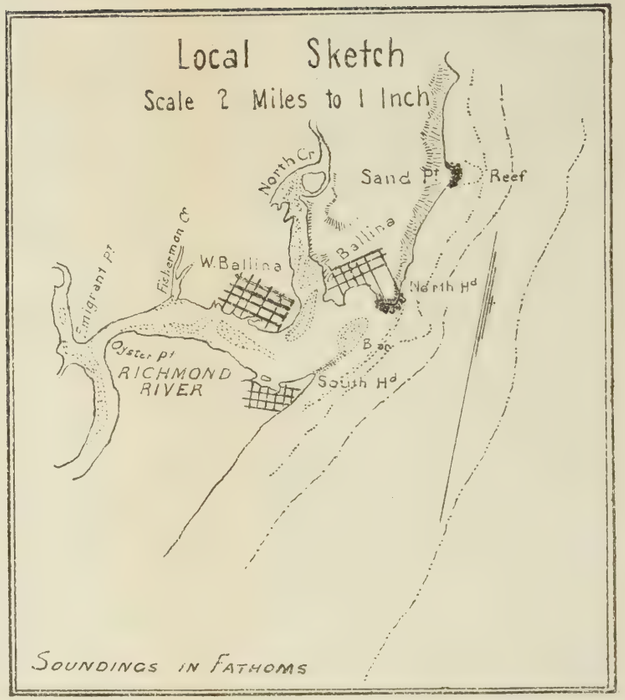
The entrance to the

Richmond River

Scale 2000 Feet to 1 Inch

SOUNDINGS IN Feet

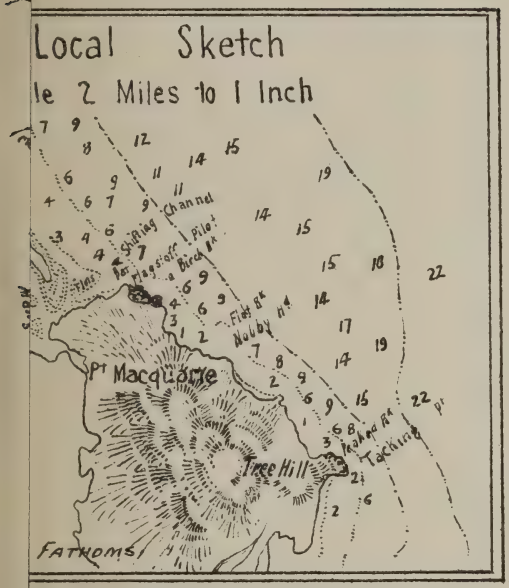




PROCEEDINGS OF THE ENGINEERING ASSOCIATION, N.S.W. SESSION 1886-87

S.W.

Plate 11


Local Sketch
le 2 Miles to 1 Inch
Channel
Pt Macquarie
Tree Hill
FATHOMS

PLAN OF

PORT MACQUARIE

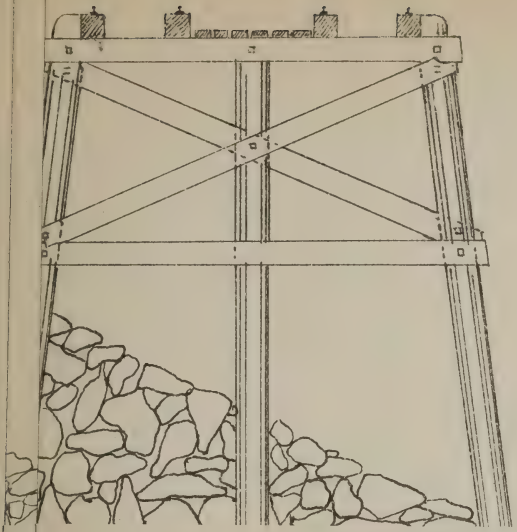
The entrance to the

Hastings River

Scale 2000 Feet to 1 Inch

SOUNDINGS IN FEET

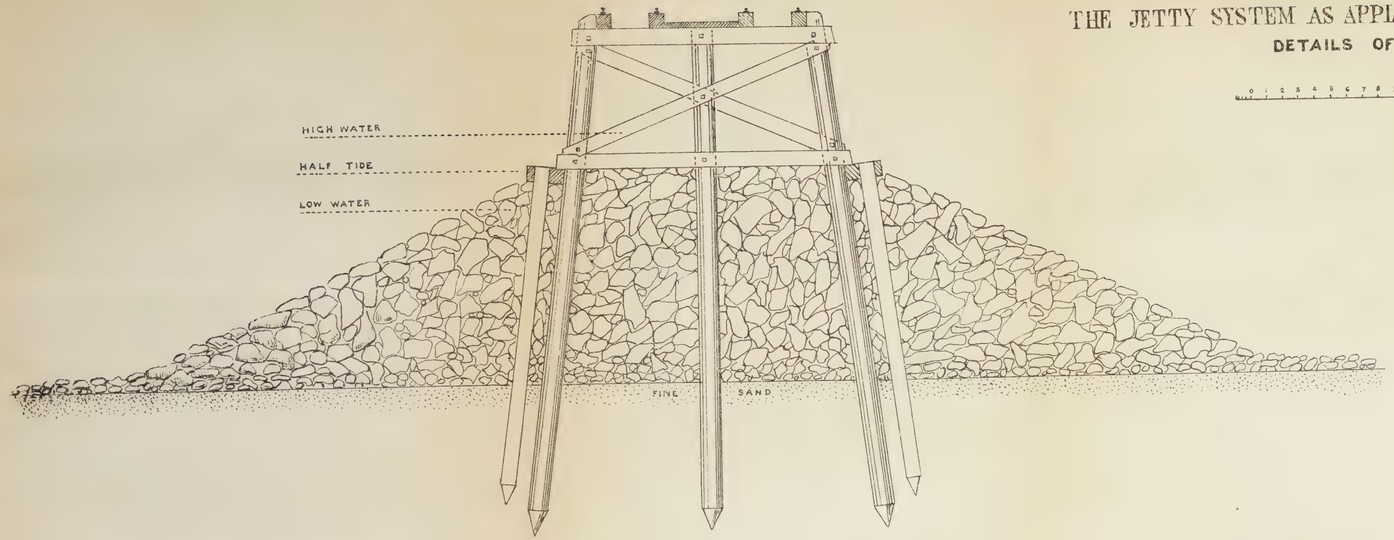
Plate III



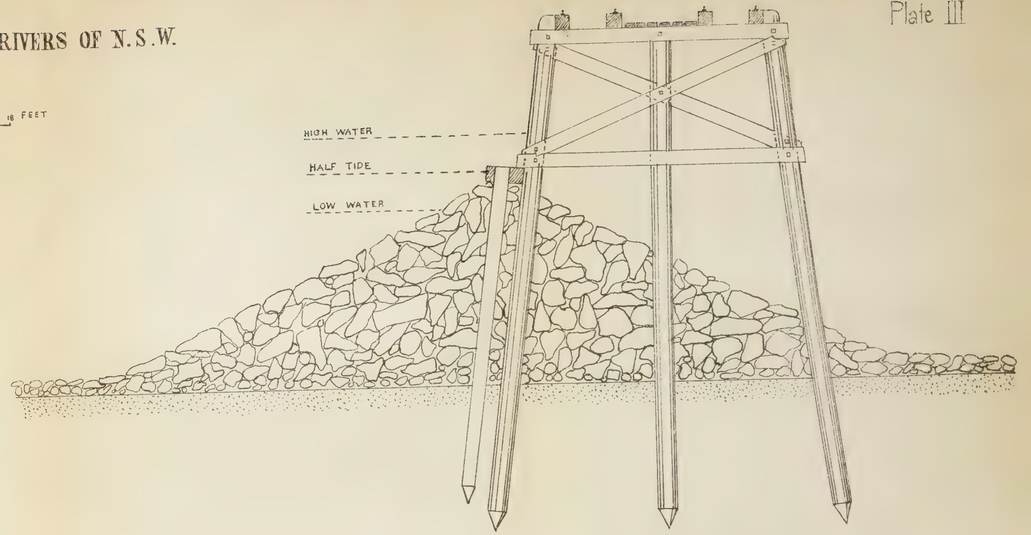
THE JETTY SYSTEM AS APPLIED TO THE RIVERS OF N.S.W.

DETAILS OF JETTIES

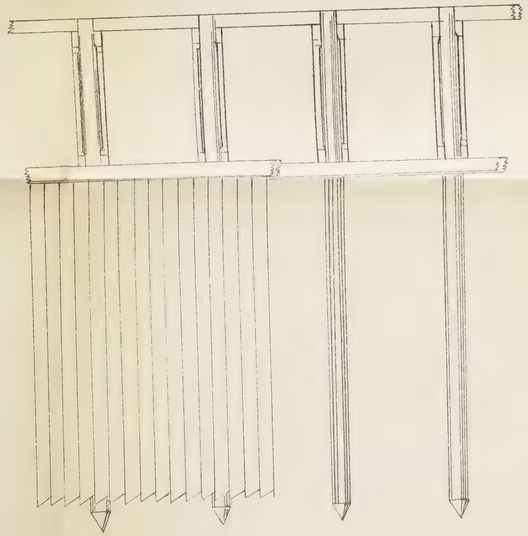
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 FEET



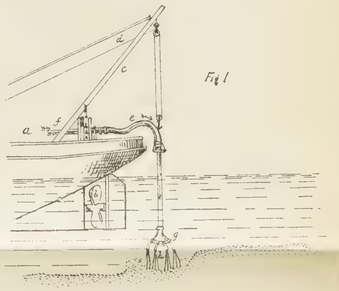
CROSS SECTION NEAR OUTER END.

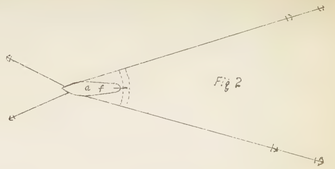


CROSS SECTION NEAR SHORE.

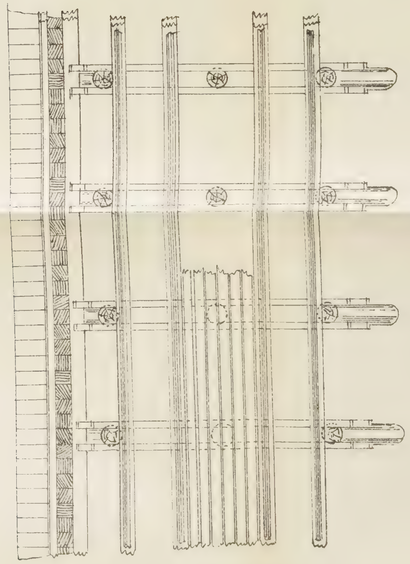


PART ELEVATION





HYDRAULIC SCOURING MACHINE



PART PLAN OF TIMBERWORK

THE SANITARY ASPECT OF THE SITE OF THE METROPOLIS AND ITS ENVIRONS

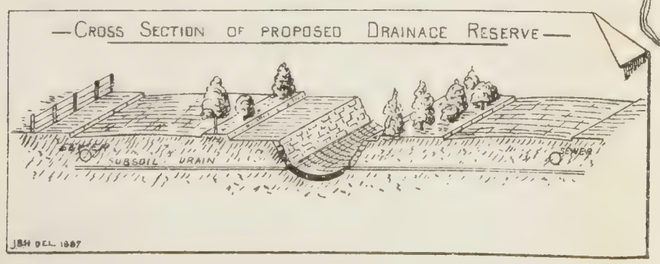
Plate IV

Sketch Plan of the Site

Scale 2 Miles to 1 inch

REFERENCE The approximate dividing line between the clay shale and the sandstone surface formations shown thus ——x——x——x——
Elevation in feet above High Water Level thus 300

—CROSS SECTION OF PROPOSED DRAINAGE RESERVE—



JBH DEC. 1887

PROCEEDINGS OF THE ENGINEERING ASSOCIATION N.S.W. SESSION 1886-87

J

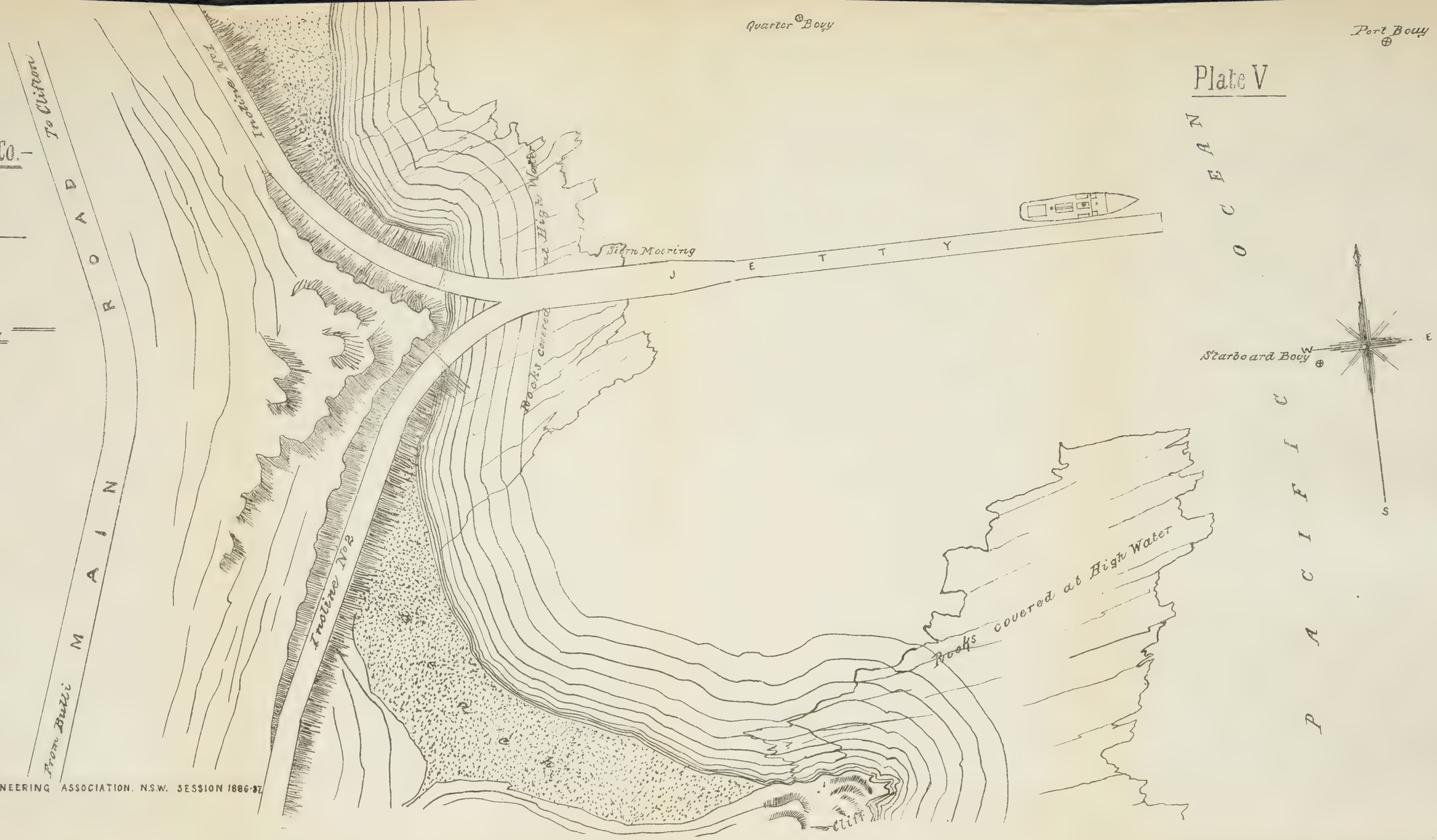
Plate V

NORTH ILLAWARRA COAL Co.

JETTY.

HICK'S BAY.

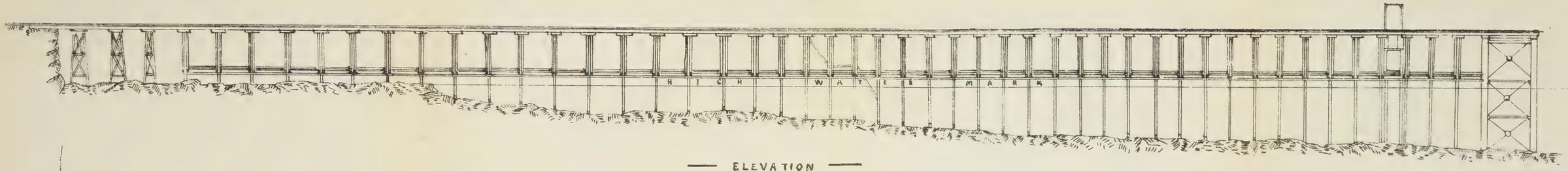
Local Sketch.



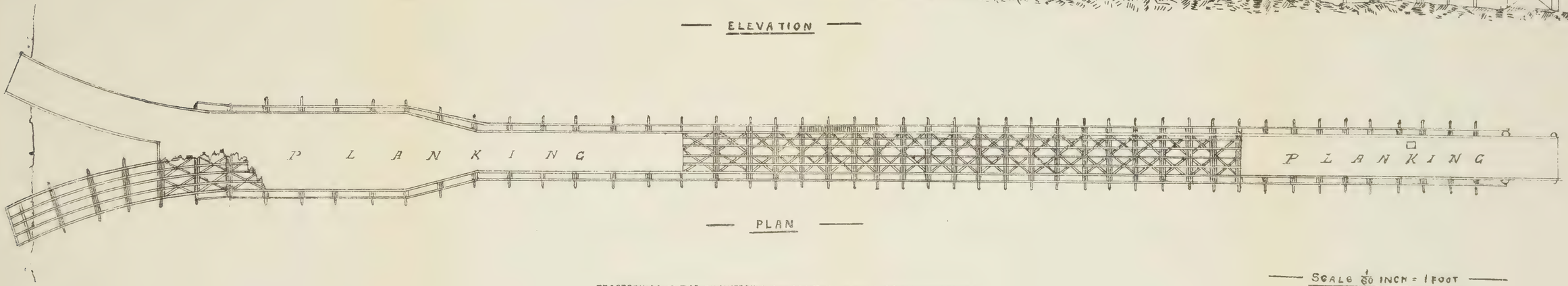
NORTH ILLAWARRA COAL CO.

JETTY

Plate VI



ELEVATION

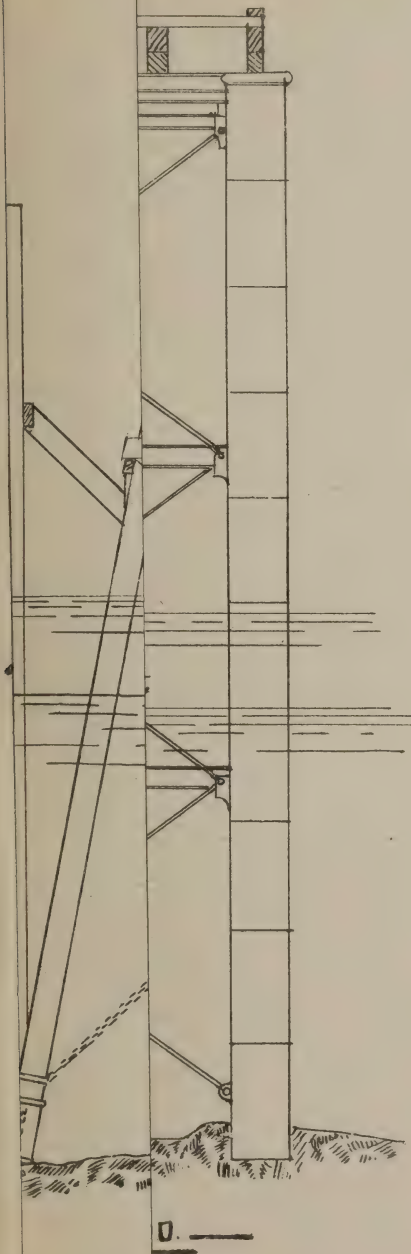


PLAN

SCALE $\frac{1}{50}$ INCH = 1 FOOT

oY

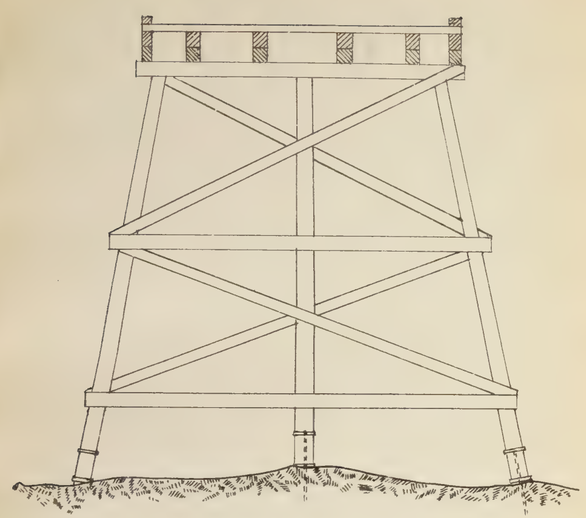
e VII



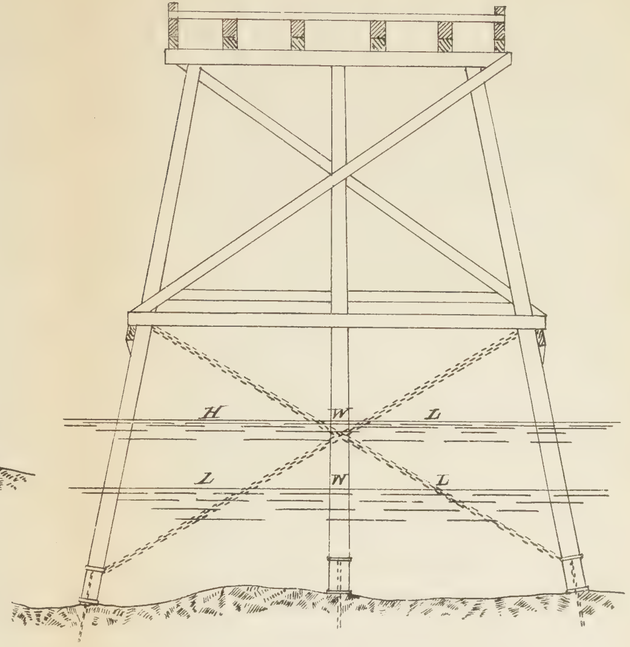
D.

JETTY FOR N.I.C.Coy HICK'S BAY.

Plate VII



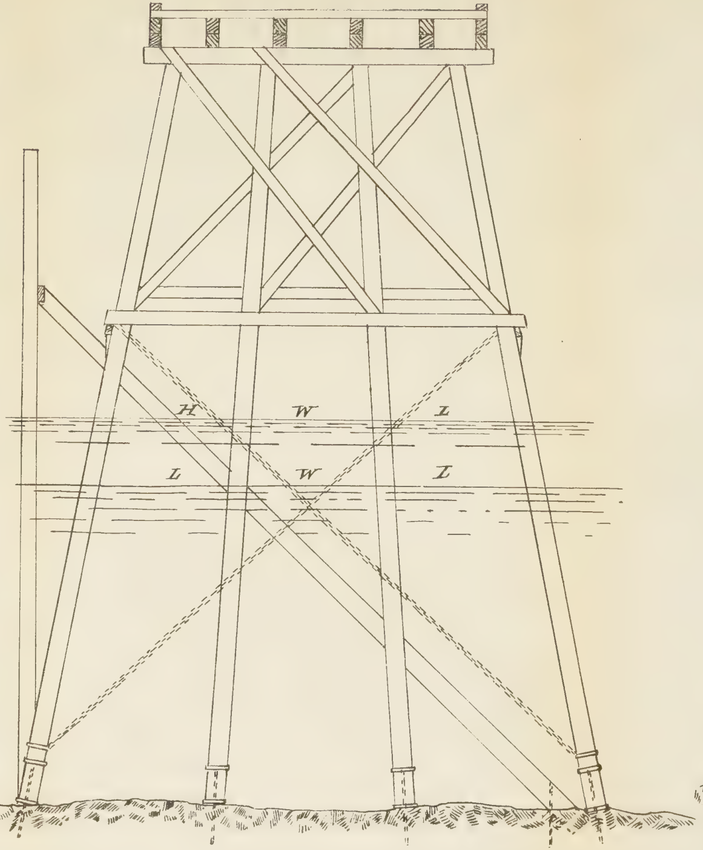
CROSS SECTION AT AA.



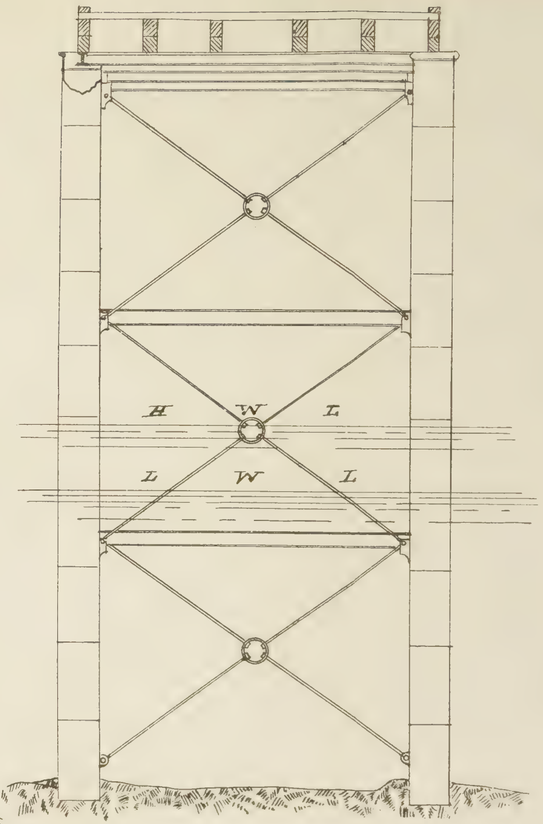
CROSS SECTION AT B.B.

SCALE

0 5 10 20 30



CROSS SECTION AT C.C.



CROSS SECTION AT DD.

PROCEEDINGS OF THE ENGINEERING ASSOCIATION N.S.W. SESSION 1887-88.

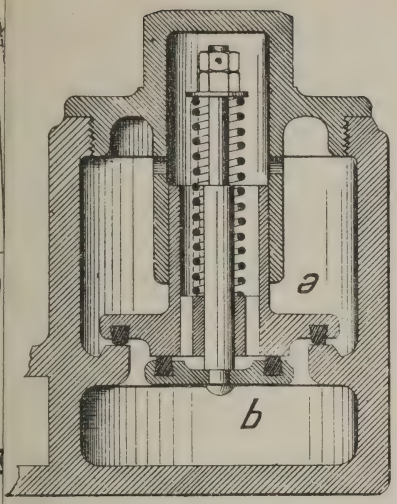
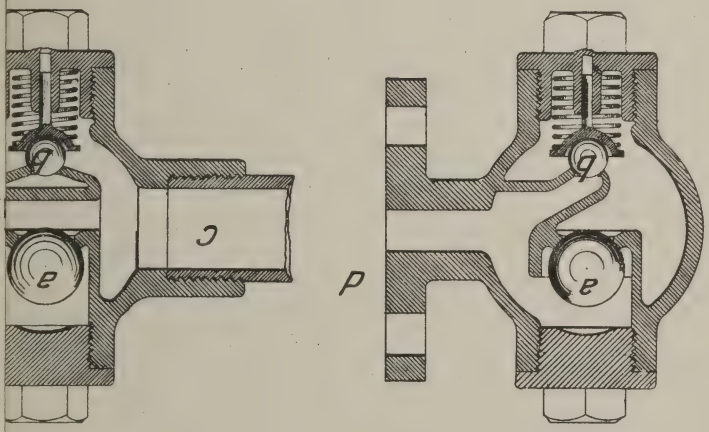


Fig. 4

ANSCOMS ORIGINAL VALVE

Fig. 5



IFICATION OF VALVE BY MR. SELFE.

& 6 are printed upside down by mistake

DESCRIPTION OF PLATE VIII.

Fig. 1 is a sectional plan of a Hanscom Brake, as fitted to a goods wagon ; Fig 2 a side elevation of same, and Fig. 3 an end view. In these three views, A is the automatic valve on "the brake on" pipe, B the chamber or reservoir, and C the bored cylinder for piston ; D is the circular slide valve on driver's valve, the details explaining themselves.

Fig. 4 represents Mr. Hanscom's original valve for A on Fig. 1, and Figs. 5 and 6 Mr. Selfe's modification of same ; *a* is the large valve to allow air into B to put on the brake and retain it ; *b* is the small valve kept closed by a spring so as always to retain pressure in B for automatic application in case of a break away.

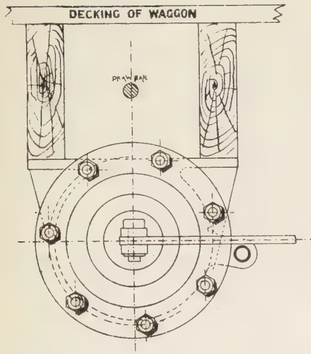
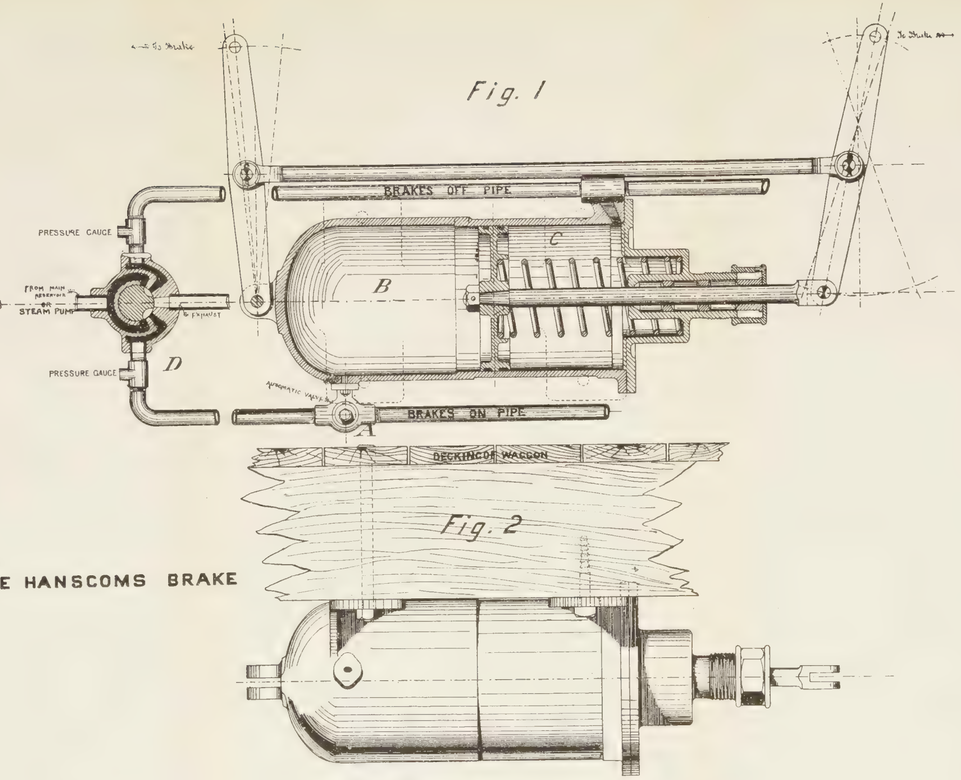


Fig. 3



GENERAL PLAN OF THE HANSCOMS BRAKE

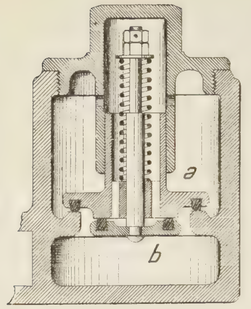
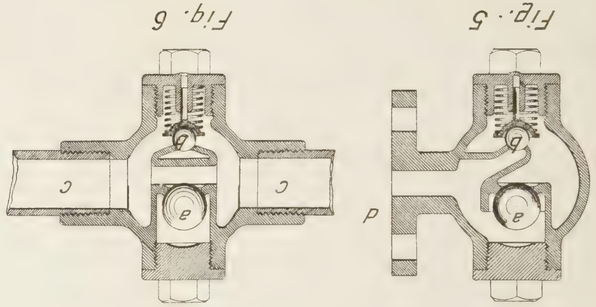


Fig. 4

Mr HANSCOMS ORIGINAL VALVE



MODIFICATION OF VALVE BY MR. SELFE.

Figs 5. & 6 are printed upside down by mistake

DESCRIPTION OF PLATE IX.

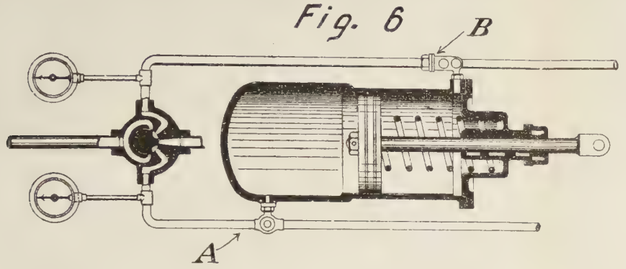
Figs. 6 and 7 show the same Brake with an instantaneous release valve for cases where the trains are long and vehicles many in number. A is the automatic valve; B the instantaneous release valve.

Figs. 8, 9, and 10 are enlarged views of valve B for instantaneous release :—*a* is the connection to train pipe, *b* the connection to reservoir or brake of brake piston, *c* opening to the atmosphere, *d* a retention valve to admit to chamber only, *e* passage to same from *a*, *f* is a passage connecting to the back of a small valve piston *h*, working in cylinder *g*, *j* is a spring to keep up *h* and valve *k*, which closes opening to *c*. It will be seen at once that as long as pressure is maintained in *a* it will be equalised on each side of piston *h*, but as soon as the train pipe pressure is reduced it will be reduced only on *g* side of *h* through the interposition of the retention valve, and thus *h* will move and open valve *k*, letting pressure out from *b* through *c* into the atmosphere until equilibrium is restored between the train pipe and back of brake piston.

Fig. 11 is similar to 8, 9, and 10, with a few additions: —*l* is an armature attracted by electro magnets *m m* when excited by a current from the foot-plate or guard's van; *n* is a valve attached to *l*. In its normal position, *n* keeps open passage *f* to the back of valve piston *h* and closes *g* from the atmosphere. The attraction of *l* overcomes the pressure of a spring, attracts *l* and moves *n*; this opens *g* to the atmosphere through passage *o* and closes passage *f*, bringing about an instantaneous movement of *h* and *k* and application of the brakes.

HANSCOMS BRAKE WITH INSTANTANEOUS RELEASE VALVE BY Mr SELFE

Fig. 6



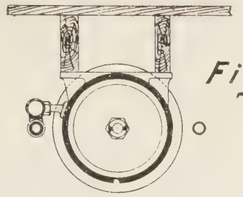


Fig. 7

INSTANTANEOUS RELEASE VALVE BY Mr SELFE

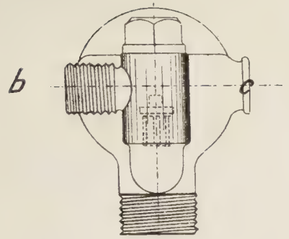


Fig. 8

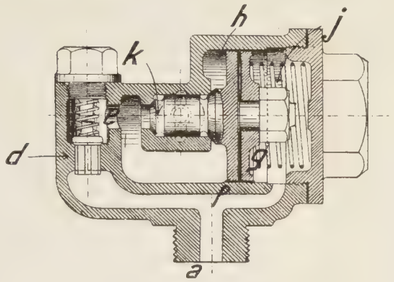


Fig. 9

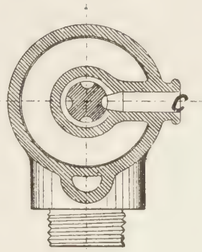


Fig. 10

ELETRO RELEASE VALVE BY Mr SELFE

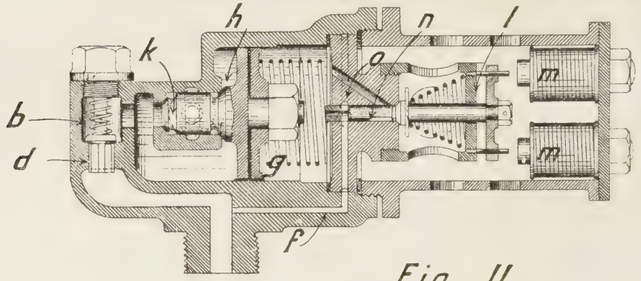
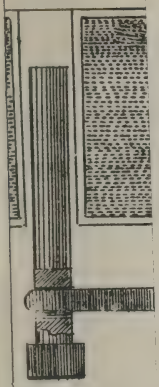


Fig. 11



FIG

FIG

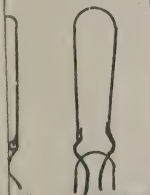
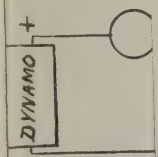


FIG Q'



FI

ELECTRIC LIGHTING.

PLATE X.

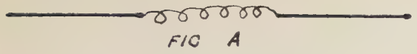


FIG A

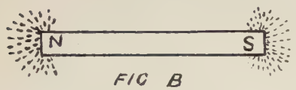


FIG B

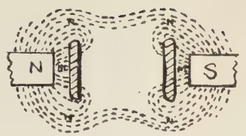


FIG C

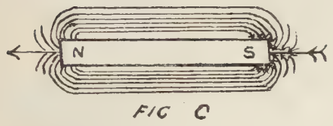


FIG C

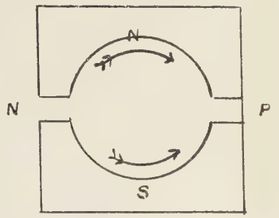


FIG H

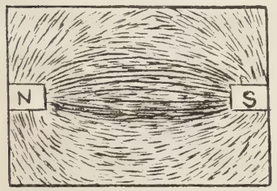


FIG D

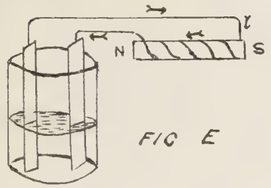


FIG E

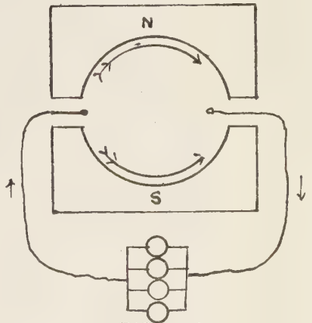


FIG I

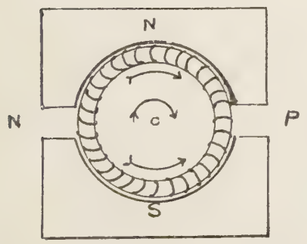


FIG F

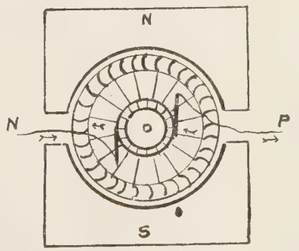


FIG J

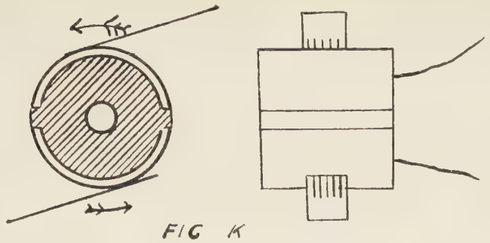


FIG K

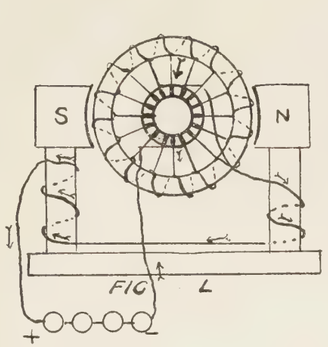


FIG L

FIG M

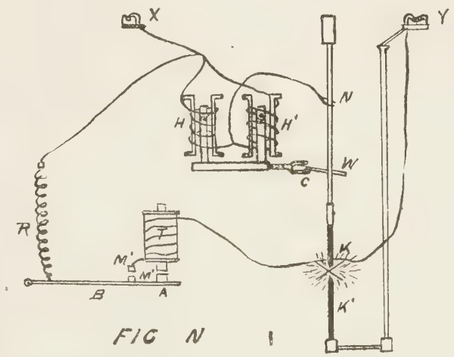


FIG N

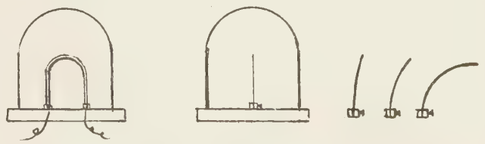


FIG Q"

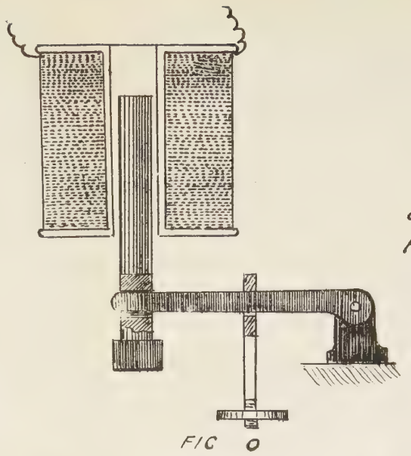


FIG O

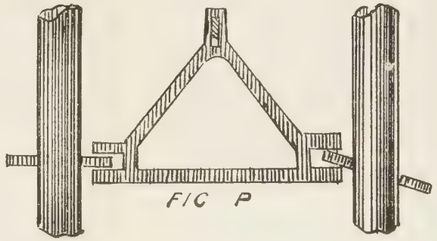


FIG P

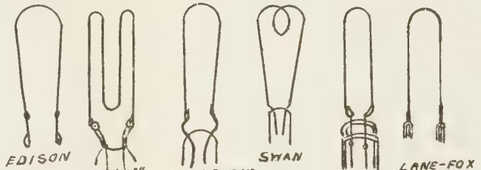


FIG Q'

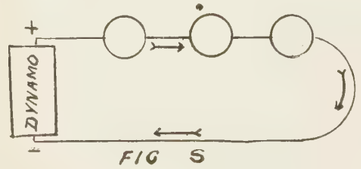
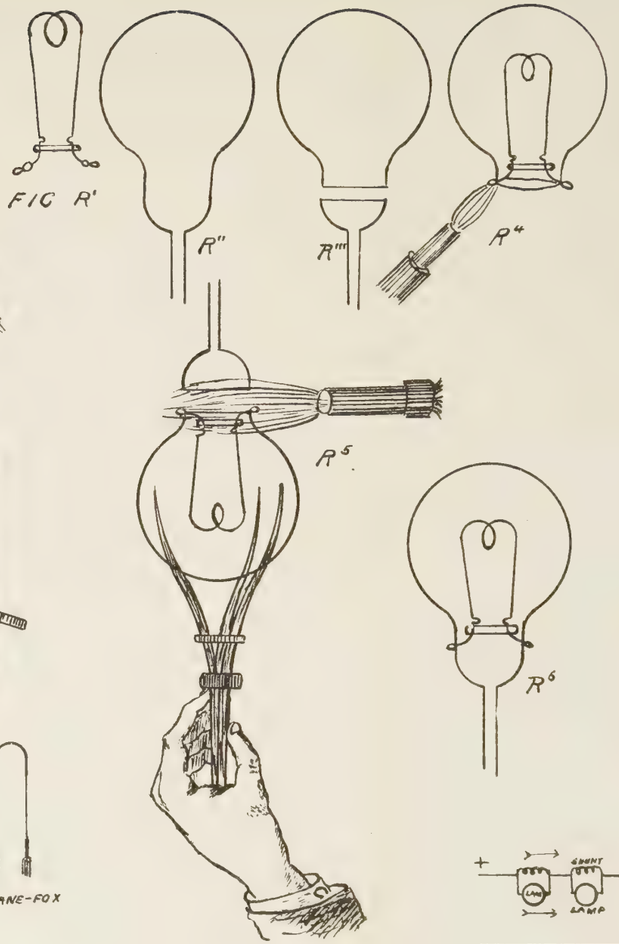


FIG S



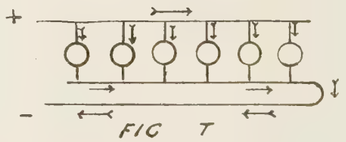
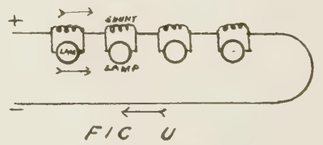


FIG T



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